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QUARTERLY RELIABILITY STATUS REPORT NAS9-150 (U)

30 September 1964

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SPACE and INFORMATION SYSTEMS DIVISION

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FOREWORD

The information contained in this report was prepared by Apollo Reliability to provide status on reliability activities for the period 15 June to 15 September 1964.

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TECHNICAL REPORT INDEX/ABSTRACT

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Project Apollo; Quarterly Report; Reliability

ABSTRACT

The document summarizes the efforts of Apollo Reliability during the quarter 15 June to 15 September 1964. Departmental support for Apollo end items, design reviews, and special programs is described. Detailed reliability information is included for each spacecraft subsystem and for mission-essential ground support equipment.

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CONTENTS

Section Page

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ILLUSTRATIONS

TABLES

I. PROGRAM IMPLEMENTATION

END ITEM SUPPORT

BOILERPLATE 13

Apollo Boilerplate 13 was launched on 28 May 1964. Prior to the flight, all minimum airworthiness requirements of mission-essential equipment had been met or exceeded (reference SID 64-704-2). All on-board subsystems had been examined for redundancy performance and possible single-point failures. Where failure possibilities did exist, investigation revealed that the probabilities of failure were sufficiently low to warrant their acceptance. The most critical area was in the electrical power subsystem. The loss of any one of three relays in the Government-furnished power control box could have caused a total loss of the primary function of the mission, the gathering of environmental data. However, two of the relays were normally closed and the third was of a latching type; the probability of any of these failing in the critical open position was very low. The overall performance of the various vehicle systems during flight was excellent.

The following paragraphs contain reliability comments on the instrumentation, electrical power, and instrumentation cooling subsystems.

Instrumentation

Only five of the 116 measurements failed to operate satisfactorily for the full duration of the flight. These failures were originally attributed to high vibration levels on measurement pickups or amplifiers which contained potential failures undetectable during ambient checkout. In certain areas of the service module, vibration levels reached over 20 g RMS between 46 and 80 seconds after launch. During this period three calorimeter measurements and one vibration measurement failed to function, and one strain gauge on the spacecraft adapter dropped out for 13 seconds. However, other similar measurements close to the ones that failed produced useful information, so the failures were either random in nature or due to local resonant conditions.

Calorimeters identical to the three which failed were subjected to additional vibration and acoustic testing, both by NASA and S&ID, which effectively eliminated these environments as failure causes. It is now suspected either that there was inadequate support to wiring and connectors or that the instruments themselves were defective. Care will be taken on future installations to provide adequate wiring support. The failure of the vibration measurement is attributed to cable clamping inadequacies. Necessary precautions are being taken to preclude recurrence of the failure.

Electrical Power

The addition of 8 cc of electrolyte to each cell of the instrumentation batteries prior to flight is recommended for future flights. This action, which is based on S&ID experimentation during months of prelaunch checkout, improved battery performance under the severe load conditions of flight and contributed significantly to the success of the Boilerplate 13 data acquisition function.

Instrumentation Cooling

The instrumentation cooling unit operated very satisfactorily during flight. Telemetry signals were received for over three orbits, and finally failed only with the exhaustion of electrical power. RF package temperatures were just starting to reach excessive values (above 150 F) during the third orbit. As a result of anomalies discovered during operational use of the Boilerplate 13 ECS pumps, the following improvements have been made:

1. The motor will be hermetically sealed and corrosion protected.
2. Following wet testing, special vacuum drying procedures will be employed to assure the removal of all fluids.
3. The assembly will be specially packaged in a pressurized container for shipment.
4. Bearing inspection requirements have been tightened.

The pumps for Boilerplate 15 and subsequent vehicles will incorporate these changes.

BOILERPLATE 15

A Boilerplate 15 reliability flight readiness report was prepared and transmitted to NASA/MSC. This report presents the efforts of Apollo Reliability toward assuring a successful launch and flight. It includes the following:

1. Summary recommendations as to launch readiness
2. Qualitative evaluation of each spacecraft subsystem

3. Identification of single-point failures within each subsystem whose successful operation is essential to the completion of primary mission objectives

4. Current status of equipment airworthiness testing

5. Corrective action provided to date on nonconformance reports

On the basis of the subsystem analyses and tests completed to date, and with the removal of the ME motor switches from the LES sequencers, Apollo Reliability recommended that the vehicle be launched on schedule. This recommendation presupposes that the electrical system displays no significant anomalies during countdown and that the GFE batteries are properly charged for flight. These precautions were recommended for the Boilerplate 13 flight as well, and are intended to minimize the occurrence of potential single-point failures in the electrical subsystem.

The Boilerplate 15 Reliability Project Engineer participated in the NASA flight readiness review at the Kennedy Space Center in September and presented the status of minimum airworthiness testing to the board. There were only two "open" items on the minimum airworthiness list, and both were GFE instruments associated with the SM RCS quadrant measurements. NASA/IESD reported that documentation of compliance with requirements was submitted to the MSC/Apollo office of Reliability and Quality Assurance. Receipt of this documentation by S&ID Apollo Reliability will close out the open items.

S&ID Reliability also recommended to the board that the flight pyrotechnic batteries be used on the second discharge cycle, in compliance with the NASA test report of 14 August 1964 confirming S&ID's prior recommendations. This report shows a significant increase in available power on the second cycle; electrical power is especially important on the Boilerplate 15 flight, since it will use more pyrotechnic devices than the Boilerplate 13 flight did.

Both S&ID and NASA reviewed the testing and analyses performed on the tower leg bolt which had broken two weeks prior to launch. Since the material met specifications and all inspection and test records indicated the part was not faulty, it was generally agreed that the bolt failed because of severe bending imposed on it during or after installation. The following actions were taken to prevent this condition from occurring on Boilerplate 15:

1. The machined thread bolts were replaced with more reliable rolled thread bolts.

2. During installation the bolt was inspected after each 50-foot-pound increment of torque to preclude misalignment.

3. An ultrasonic test of the installed bolts was performed after six days on the vehicle, and no cracks were observed.

To increase the reliability of future boilerplate single-mode tower bolts, only rolled threads will be used and spherical washers will be added on the lower end of the bolt.

The board supported a recommendation by the Chairman that a resistance check of pyrotechnic initiators after installation be made a regular part of KSC launch procedures. This check will assure the integrity of the pyrotechnic circuitry after final preparations for flight.

REORIENTED QUALIFICATION TEST PROGRAM

The Apollo Qualification Test Program was reoriented during July 1964 to ensure a maximum uniformity of test techniques and to provide a more efficient Block I and II time phasing. Initially, the test program was divided according to three distinct groupings of mission requirements:

Unmanned earth orbit
Manned earth orbit
Lunar orbit rendezvous

Subsystem and component criticalities were based on these mission requirements. With the reorientation of the program, ground rules were established for qualification testing in the following categories:

Manned earth orbit (Block I worst-case)
Lunar orbit rendezvous (Block II worst-case)

More recently, these same ground rules have been redefined into three categories:

Those specifically applicable to Block I
Those specifically applicable to Block II
Those common to both Block I and II

The effort of reorienting the Qualification Test Program and assuring a timely completion of tasks will continue during the next quarter.

DESIGN REVIEW BOARD

Table 1 summarizes the Apollo Design Review Board activity during last quarter.

Table 1. Design Review Status

No.	Review Subject	Type of Review	Date Conducted	Approval Status
50	Boilerplate No. 23	Preliminary	6-12-64	Approved
54	C14-211, -213, ACE signal conditioning equipment	Major	6-8-64	Withheld*
64	CM Heat shield ablator	Major	6-11-64	Approved
65	Boilerplate No. 26	Preliminary	6-5-64	Approved
66	SM structures	Major	6-11-64	Approved
67	SM propulsion tanks and system support	Major	6-19-64	Approved
68	System support provisions and space allocation in SM	Major	6-28-64	Approved
70	HF transceiver and VHF-FM transmitter	Preliminary	6-16-64	Approved
71	Premodulation processor equipment	Preliminary	6-12-64	Approved
73	A14-139A, pyrotechnic initiator substitute unit, and C14-480, initiator stimuli unit	Major (Re-review)	8-13-64	Approved

*See discussion following this table.

Table 1. Design Review Status (Cont)

No.	Review Subject	Type of Review	Date Conducted	Approval Status
74	Unified S-band and S-band power amplifier	Preliminary	6-30-64	Approved
75	C14-240-101, ACE-SC adapter servicing equipment	Major (Re-review)	6-24-64	Withheld*
76	Antenna switching equipment	Preliminary	6-22-64	Approved
77	Data storage and flight qualification recorder	Preliminary	7-1-64	Approved
78	Fluid distribution control special test units: C14-466, -447, -448, -449, -476, -477, -478, -479, -488, and -489	Major	7-6-64	Approved
79	Electrical power distribution	Major	7-17-64	Approved
80	VHF-AM transceiver and recovery beacon	Preliminary	7-10-64	Approved
81	C14-605, -606, CM and SM RCS checkout control group	Major	7-17-64	Approved
82	TV camera	Preliminary major	7-21-64	Approved
83	Master events mission sequencer	Preliminary major	8-5-64	Approved
85	C14-455, SPS remote control unit	Major	8-3-64	Approved

*See discussion following this table.

Table 1. Design Review Status (Cont)

No.	Review Subject	Type of Review	Date Conducted	Approval Status
86	Cryogenic gas storage system	Major	7-31-64	Approved
88	Central timing equipment	Major	8-12-64	Approved
89	CSM separation ordnance systems	Major	8-6-64	Approved
91	C14-602, SPS checkout and fire control unit	Major	8-19-64	Approved
92	C14-075-201, propulsion system checkout unit	Major	8-18-64	Withheld*

*See discussion following this table.

ACE SIGNAL CONDITIONING EQUIPMENT

Design Review Board approval was withheld on the C14-211 and -213 for the following reasons:

1. Current procurement specifications include an altitude requirement of 450,000 feet, which appears to penalize fabrication and assembly costs of this equipment. Value Engineering has been assigned the task of determining if this design constraint affects costs and whether this problem warrants a full study.

2. The present procurement specification does not list cleanliness requirements for this equipment and its installation inside the command module. The DRB recommended that the Apollo Contamination Control Board be requested to provide cleanliness requirements.

3. The expected operating time of the ACE carry-on equipment is 62 hours; the current predicted MTBF is 59 hours. Rapid methods for fault isolation and maintenance must be established. The major problem exists at T-28 hours to T-5 hours, when the allowable downtime for repairs is 15 minutes in any three-hour period. The board recommended that action in item 1 of design

review 53 (see Tenth Quarterly Reliability Status Report) be extended to cover the C14-211 and C14-213 as well. This action item covered the investigation of drawer sparing, instead of the present sub-module repair and sparing concept.

4. According to reliability and GSE requirements, the ACE carry-on equipment will be installed at T-72 and removed at T-5 hours. Photographs of a command module mockup containing the ACE carry-on equipment show a cable density which would present a very difficult access problem. The board recommended that the installation of the ACE equipment be reevaluated to allow easy access and maintenance, in conjunction with item 3 above.

ACE SERVICING EQUIPMENT

Approval was withheld on the C14-240-101 because the design reliability estimate is less than half of the reliability required of the system. The reliability can be improved by reducing maintenance time or incorporating redundancy for priority data (see design review 32, Tenth Quarterly Reliability Status Report).

Progress on this reliability-maintainability problem, also discussed in the last report, has been satisfactory, but operating reliability goals still cannot be met and design approval continues to be withheld.

PROPULSION SYSTEM CHECKOUT UNIT

Design approval was withheld on the C14-075-201, pending satisfactory resolution of the following items:

1. The range of the selected low-flow turbine meter does not meet the minimum design low-flow measurement requirements of the RCS.

2. The location of the turbine meters is not compatible with the RCS and SPS design test requirements.

3. The location of the air flow temperature sensing device is unsatisfactory, since, in this position, it will not accurately sense the test fluid temperature.

4. The test unit cannot measure the RCS helium check valve reverse flow leakage, as required by spacecraft design.

5. The Spacecraft Design group (RCS) is requesting a change in the method of checking regulator lockup pressure. The new method requires a 100-cubic-inch ullage tank immediately downstream of the regulator. The process specification will be changed accordingly.

6. The test unit is incapable of measuring regulator (primary and secondary) seat leakage during a high-pressure lockup test.

7. Adequate evaluation of helium relief valve performance during flow tests requires that a pressure gauge be placed next to the valve undergoing test. The present configuration only measures the system supply pressure at the test unit.

8. Present acceptance test procedures do not require system structural integrity, proof pressure, and system relief valve functional testing to be performed.

STATUS OF ECS DESIGN REVIEWS 18 AND 19

Action items resulting from design reviews 18 and 19 of the pressure suit, oxygen supply, pressure and temperature control circuit, water glycol circuit, and water supply subsystem are discussed in the section on the environmental control system.

TRAINING AND EDUCATION

The technical courses and seminars presented by Reliability during the report period are listed in Table 2.

Table 2. Reliability Classes and Symposia

Title	Number of Presentations	Average Attendance	Total Student Hours
Fundamentals of reliability mathematics	8	6.4	77
Design analysis techniques	10	6.5	98
Computer methods of analysis	1	9.0	14
Symbolic/Boolean logic	3	9.3	42
Nonconformance reporting system	18	12.6	678
S&ID instrumentation engineers	1	29.0	87
Total	41	24.3	996

NONCONFORMANCE REPORTING SYSTEM

A 3-hour familiarization course on the nonconformance reporting (NCR) system was developed and presented to personnel who are or will be frequently involved with the system. The content of the course is outlined below:

I. INTRODUCTION. What the NCR system is, the need for such a system, the importance of the system to the Apollo program, and the subjects which will be discussed during the course.

II. THE NCR SYSTEM. Look at the overall NCR system and the differences between it and the material review system; definition of a "nonconformance," as distinguished from a "squawk"; NCR system functional flow.

III. RESPONSIBILITIES. Outline of the functional responsibilities of the S&ID organizational groups involved in the NCR system.

IV. SYSTEM IN DETAIL. Detailed discussion of each of the four major functions of the NCR system, as follows:

A. Reporting. Each block on the NCR form: entry required, source of information, and information not available or not applicable; responsibilities for initiating the form and completing its various parts, for initial and assessment contracts, and for decisions to be made prior to completion of the form; form transmittal, verification, and voiding; handling of hardware in connection with the report requirements.

B. Assessment. Responsibilities of the assessment engineers, reliability analysts, and design engineers in determining the action to be taken; initiating the action; requesting analysis (in-house, subcontractor, or supplier) and preventive action; routing hardware for analysis or disposition; coordinating with customer on customer-furnished items.

C. Analysis. Procedures to obtain analysis; analysis report; action to be taken upon completion of analysis; responsibilities for these actions.

D. Preventive Action. Procedures to obtain preventive action; forms required; responsibilities; follow-up action; completion of nonconformance action.

V. SUMMARY. Brief review of the total system, its need, and its importance; paper and hardware flow; where to direct inquiries, suggestions, and constructive criticism.

PRIDE PROGRAM

S&ID instituted the PRIDE program (personal responsibility in daily effort) as a division-wide employee motivational program. Reliability Education cooperated with other divisional groups to promote the program.

The PRIDE program was inaugurated with the following specifics:

1. Initial publicity was carried in the 21 August 1964 edition of the divisional newspaper, Skywriter.

2. The first of a series of 12 posters was displayed throughout the division.

3. Supervisors were issued PRIDE badges to distribute to their personnel. This provided the supervisor an opportunity to discuss the importance of personal responsibility with employees.

The program will continue under the divisional PRIDE Program Administration. The functional departments will provide the services; data evaluation, and correction techniques necessary for program success. Management understanding participation, down to first-line supervision, is mandatory to achieve the objectives of the program. Major effort will be exerted toward preventing defects rather than the more costly process of after-the-fact detection. This will be accomplished by the following:

1. Maintaining policies that recognize the value of each individual's capabilities and performance

2. Establishing standards for all involved personnel categories

3. Measuring and evaluating performance to prevent problem development

4. Implementing local controls and evaluation techniques for employee experience, training, capabilities, and job performance

Basic features of the program, which will provide for training, motivation, detection, correction, and evaluation, include the following:

1. An information system flexible enough to indicate the responsibility for and the nature of defects; the traceability of defects to the leadman level

2. A method of classifying defects that will grade quality problems according to their significance

3. The establishment of a defect level that will indicate the need for corrective action

4. An audit program that will measure the ability of the inspection activity to prevent defect escapes to the customer, measure inspection performance, and estimate the outgoing quality level of the product

5. A standardized charting and reporting system

6. A positive coordination activity between the administrative services, functional division departments, and the Apollo program.

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VIDEOFILMS

Thirty-nine requests for motivational and educational Reliability videofilms were honored during the report period. Table 3 shows the distribution of these aids.

Table 3. Videofilm Distribution

Recipient \ Title	Apollo Challenge	Apollo Mission	Boilerplate Number 6	Design Review	Design Review Participation	Identification and Traceability	100,000 Astronauts
American Brakeshoe						x	
Amphenol Incorporated	x	x					
AVCO Corp.		x					
Beech Aircraft				x	x		
Douglas Aircraft				x			
Eldon Fiberglass							x
Elgin National Watch			x				
General Electric				x			
General Precision				x			x
ITT Cannon Electric	x	x			x	x	x
Lockheed Propulsion		x	x	x			
Marquardt Corp.		x	x	x			
NAA, Columbus Division			x				
NAA, S&ID, Compton		x					
NAA, S&ID, Downey		x		x		x	
NAA, S&ID, Huntsville						x	
NAA, S&ID, Pico Rivera							x
Northrup-Ventura		x					
Pacific Telephone and Telegraph		x					
Pratt & Whitney				x			
Radcom-Emertron		x					
Simmonds Precision Products		x		x			
Space Ordnance Systems		x					
Teleflex		x					
Tite-Flex Corp.						x	

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TECHNICAL INTEGRATION

DATA SYSTEMS DEVELOPMENT

Nonconformance Reporting System

Programming of the NASA/MSC failure tape was completed. The reporting of data to the customer by magnetic tape is a new technique; it eliminates the prior requirement for typewritten reports and has already set a precedent in rapid delivery of data to the customer.

As of 1 September 1964, the NCR report generator has produced approximately 750 individual reports in support of the reliability program. The report generator is a sophisticated data processing program which has the capability of producing a large quantity of variable reports, depending upon the needs of the user. It has been in service since 30 September 1963.

Operating Time Data System

Phase I programming has been completed, except for updating the facility and occurred-during-code tables. The program has been checked out with pseudo test data, and a plan is being formulated to encode currently available Apollo data for input to the system.

Traceability and Configuration System

The programming effort for this system is now considered complete, and the system is in service. A few discrepancies remain in the system; they are being manually corrected until program revisions can be made. The backlog of data to be converted to this system is now down to 12, 000 transmittals.

NONCONFORMANCE REPORTS

During this report period, 5736 nonconformance reports (NCR) were reviewed, processed, and transposed to transmittal sheets. These sheets are stored by Data Processing and can be retrieved mechanically as required on printouts. Printouts showing weekly and monthly tabulations and accumulated monthly NCR activity are distributed regularly to

Quality Control, Design, Reliability, and Logistics Engineering. Print-outs of specific data are being requested at an average rate of 40 per month. Statistical qualitative and quantitative problem reports have been prepared and issued to document the distribution of various nonconformance conditions (type of NCR, cause, location, facility, part condition, occurred during, symptom, problem description, disposition, end item model, subsystem, and analysis or corrective action if required).

The NCR's reviewed by the data analysts are categorized in Table 4. Figure 1 shows the cumulative total of nonconformance reports received by Technical Integration, and Figure 2 graphs the status of S&ID NCAR's and CAR's.

Table 4. NCR Classifications

REPORTS PER SUBSYSTEM	
Subsystem	No. of Reports
Structures and heat shield	2110
Environmental control	712
Electrical power	269
Instrumentation	224
Propulsion	140
Reaction control	130
Crew provisions	95
Earth landing	87
Telecommunications	73
Pyrotechnics	49
Launch escape	19
Stabilization and control	7
Not assigned to subsystem*	196
Ground support equipment	1599
Mission simulator	26

*Standard parts (material, capacitor, terminal board, etc.)

[redacted]

Table 4. NCR Classifications (Cont)

REPORTS PER NONCONFORMANCE CATEGORY	
Type of Nonconformance	No. of Reports
Failure	225
Discrepancy	5276
Unsatisfactory condition	230
Other	5

REPORTS PER CAUSE CATEGORY		
Cause*	No. of Reports	Percent of Total
Operator error	1289	22.5
Workmanship	1180	20.6
Unknown	1539	26.9
Tooling (defective or inadequate)	500	8.7
Mishandling	183	3.2
Processing error	155	2.7
Improper assembly	132	2.3
Design inadequacy	130	2.3
Planning error	121	2.1
Defective material	121	2.1
Written procedure	101	1.8

*The mission simulator and ground support equipment accounted for 28.4 percent of the problem reports.

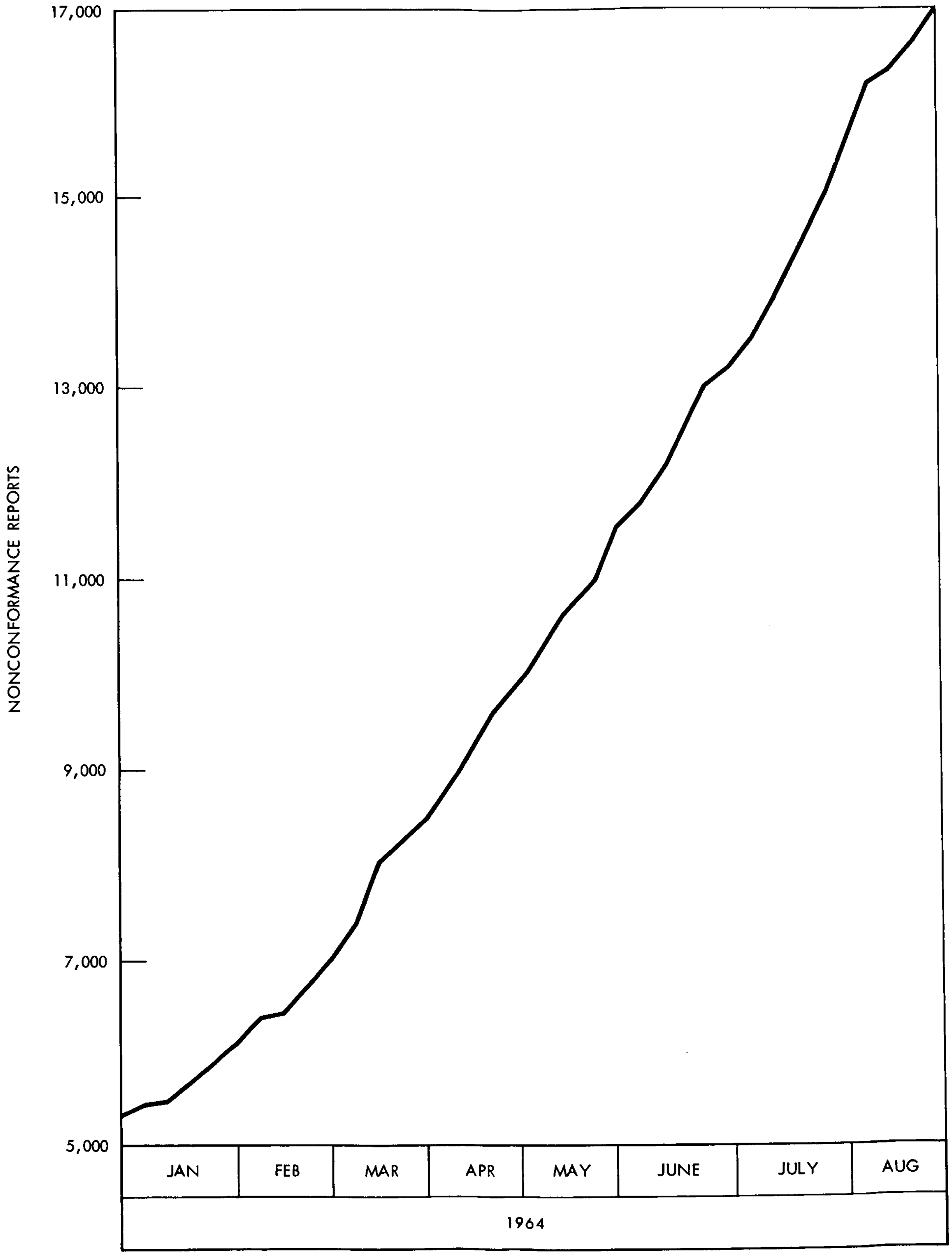

Figure 1. Cumulative NCR's Received

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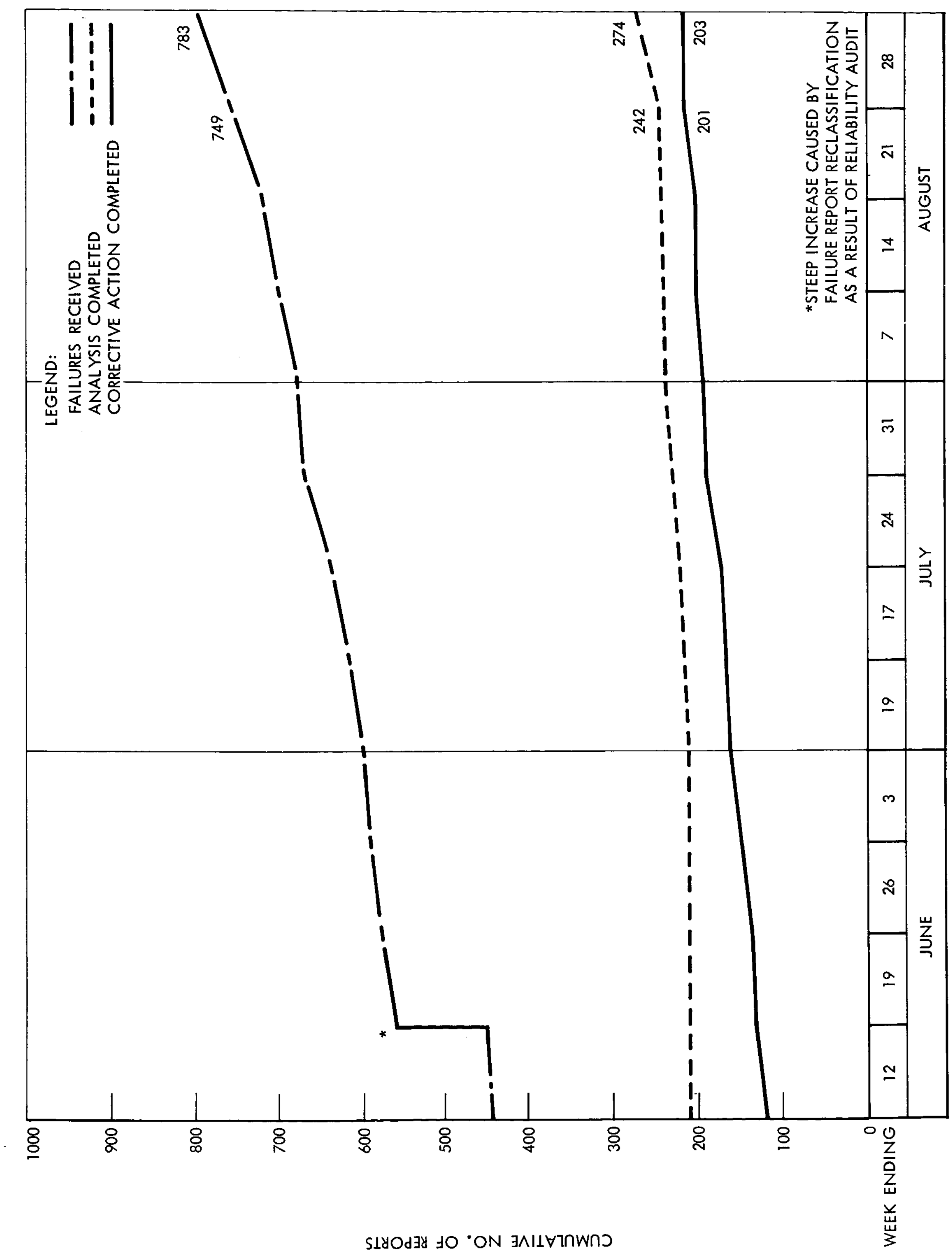

Figure 2. NCAR and CAR Status

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SUBCONTRACTOR/SUPPLIER DATA ACTIVITIES

The flow of supplier test data failure reports to S&ID is continuing to increase as subcontractors and suppliers progress into their programs. During this report period, 446 reports were reviewed and processed for storing in the data bank. Monthly supplier failure summaries (either tabulated reports or Data Processing printouts), delineating end item model, problem, cause, part condition, occurred during, department and facility, disposition, analysis of problem, and corrective action taken, are prepared and issued to concerned groups.

The supplier problem reports reviewed by the data analysts are categorized in Table 5. Figures 3 and 4 show the composite status of subcontractor/supplier failure reports. Table 6 shows reporting status according to individual company.

The failure reports received from subcontractors and suppliers showed the following significant problem areas:

1. AiResearch. Thirty-seven reports concerned valve malfunctions (sticking, leaking, or contamination).
2. Beech Aircraft. Nineteen reports concerned disconnect valve problems; the valves were redesigned to preclude future problems.
3. Collins Radio. Fourteen failure reports (40 percent) involved signal conditioning equipment, of which 10 were caused by a dc differential amplifier and 4 by diodes.
4. Microsystems Inc. Fourteen failure reports concerned transducers (12 pressure and 2 temperature). Of these problems 7 were caused by improper assembly, 5 by testing errors, and 1 by defective material; the cause of one failure is unknown.

Table 5. Subcontractor/Supplier Failure Report Classifications

REPORTS PER SUBSYSTEM	
Subsystem	No. of Reports
Environmental control	111
Telecommunications	86
Ground support equipment	49

[redacted]

Table 5. Subcontractor/Supplier Failure Report Classifications (Cont)

REPORTS PER SUBSYSTEM (Cont)

Subsystem	No. of Reports
Stabilization and control	46
Electrical power	43
Reaction control	41
Propulsion	33
Instrumentation	19
Launch escape	7
Earth landing	6
Pyrotechnics	5

REPORTS PER NONCONFORMANCE CATEGORY

Type of Nonconformance	No. of Reports
Failure	330
Discrepancy	112
Unsatisfactory condition	2
Other	2

REPORTS PER MAJOR CAUSE CATEGORY

Cause	No. of Reports	Percent of Total
Unknown	129	29.0
Design inadequacy	76	17.1
Improper assembly	72	16.1
Defective material	34	7.6
Workmanship	24	5.4
Testing error	23	5.3
Written procedures	20	4.5
Contamination	16	3.7

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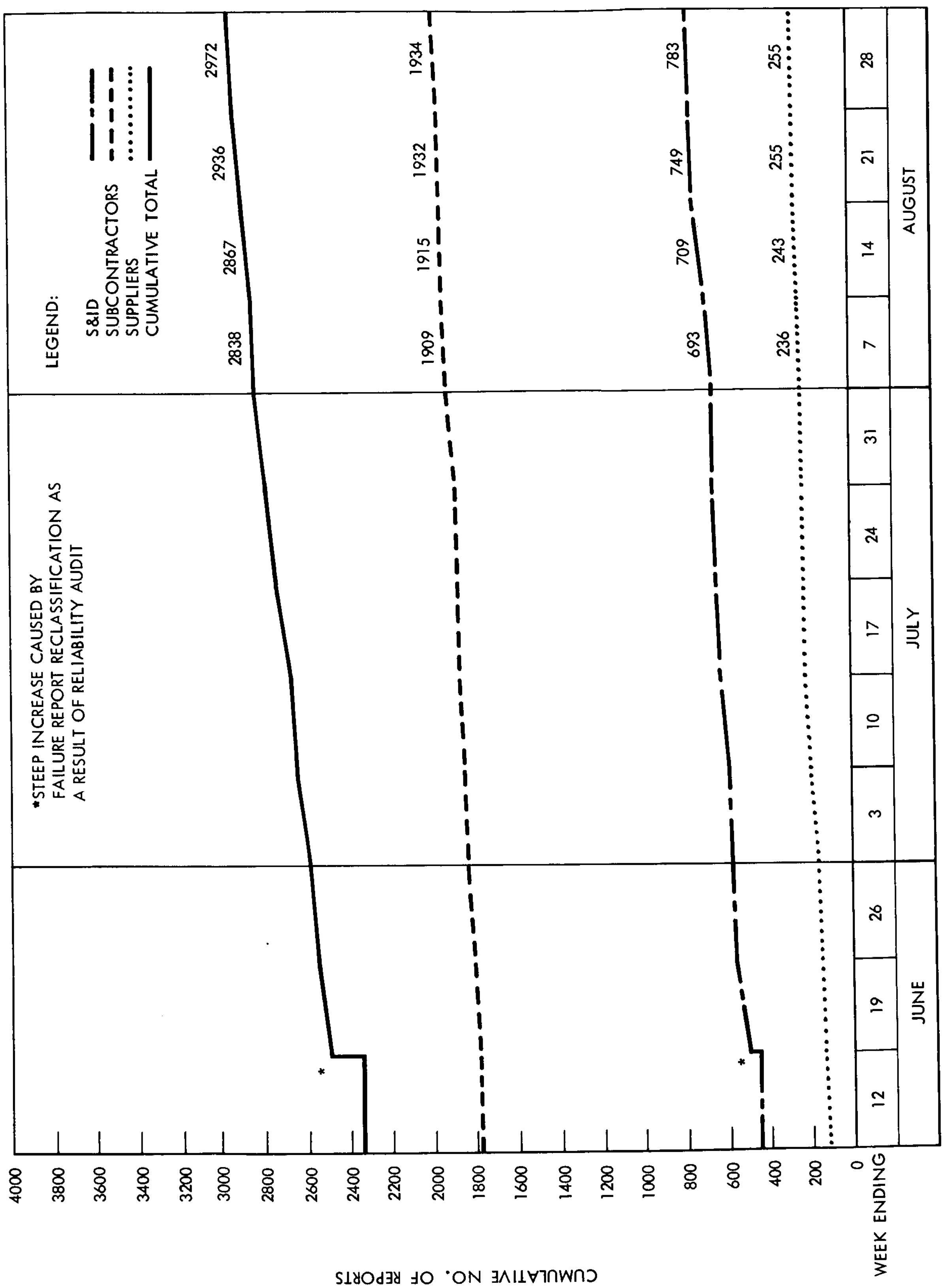

Figure 3. Subcontractor, Supplier, and S&ID Weekly Failure Report Status

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[redacted]

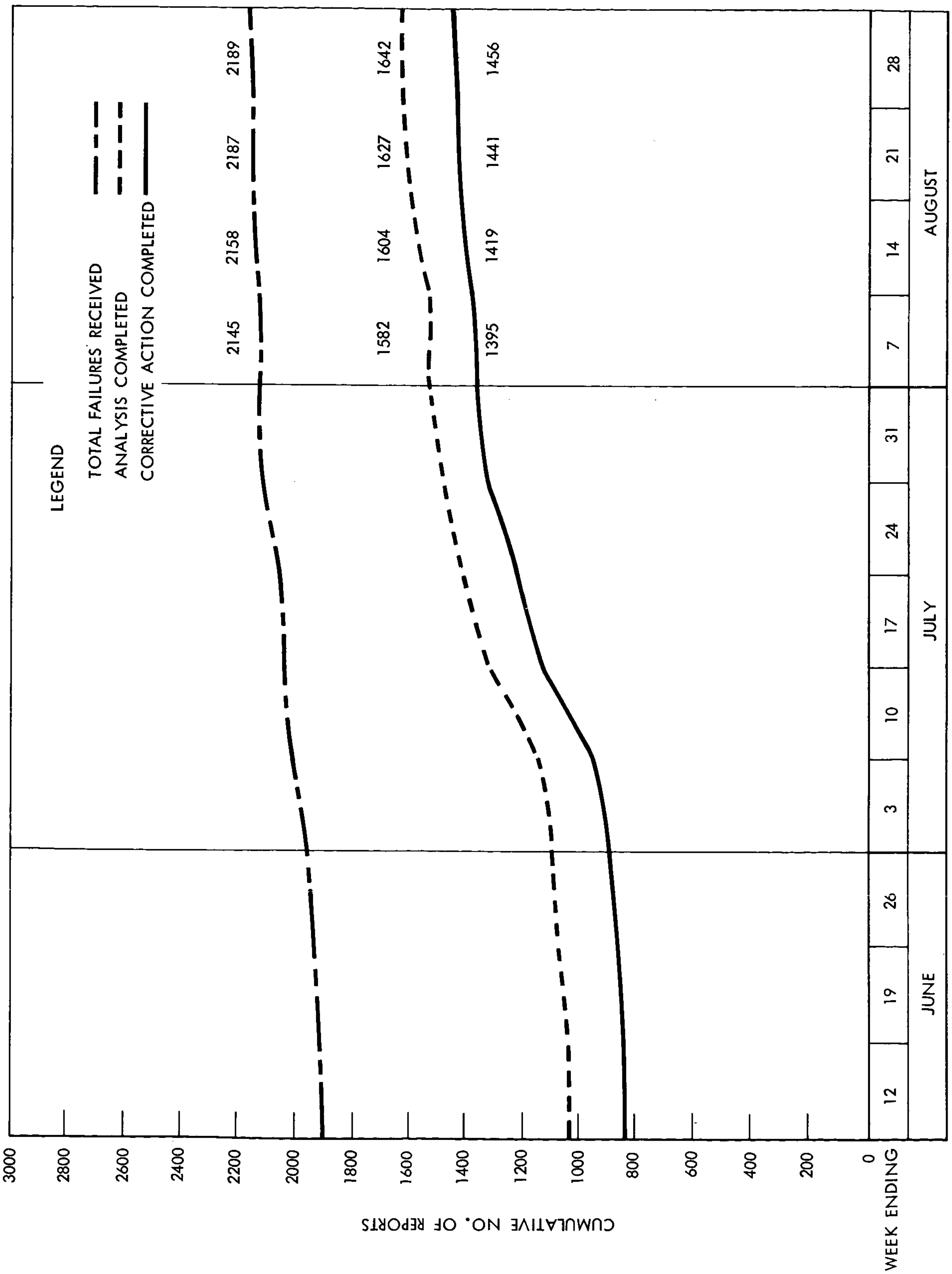

Figure 4. Subcontractor/Supplier Analysis and Corrective Action Status

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Table 6. Composite Report Processing Status

Company	Total Reports	Total Analyses Received	Average No. Days from Failure Report Initiation to Receipt by S&ID				Average No. Days from Analysis Report Initiation to Receipt by S&ID			
			May	Jun	Jul	Aug	May	Jun	Jul	Aug
Minneapolis-Honeywell	1,215	842	19	20	22	16	48	52	53	58
Northrop-Ventura	295	138	25	25	25	3	50	39	39	3
Marquardt	32	20	26	26	25	23	61	61	57	57
Rocketdyne	93	61	76	64	64	64	181	148	148	38
Aerojet-General	179	146	23	24	23	23	69	64	63	38
Beech Aircraft	81	63	20	21	21	11	38	34	34	23
Collins Radio	207	121	41	36	34	28	58	56	56	58
AiResearch	99	47	43	40	39	23	32	34	36	53
Lockheed	15	8	20	20	20	20	18	18	18	18
Pratt & Whitney	93	86	23	23	23	16	47	47	47	38
Subcontractor Total	2,313	1,534	32	30	30	32	60	55	55	38
Supplier Total	290	128	43	40	37	22	46	48	48	46
S&ID Total	17,519	206	14	13	12	6	20	21	26	19

[redacted]

5. Marquardt. Significant problem reports were received on excessive chamber pressures at the time of reignition during pulse tests. The preigniter concept was successful in reducing this excessive pressure spike.

6. Rocketdyne. Problem reports concerning vibration amplification in propellant valves resulted in design changes to the valve mounting bracket. Ablative throat inserts were eliminated from the engine design consideration because they would probably decrease performance and reduce the reliable life of the engine. A JTA-graphite throat insert has eliminated the cracking problem associated with the previous silicon-carbide insert.

7. Aerojet-General. Problem reports on the dynamic instability of injectors have been received. Instability was a major problem during the design and development stages of this hardware and, along with other design inadequacies, has caused a high propellant valve rejection rate.

SCRAP REPORTS

During this report period, 709 scrap reports, involving 2821 parts, were processed, tabulated, and issued as monthly summary reports to concerned organizations. A scrap report summaries list items that are reported through the NCR system. The parts with the highest scrap rates were the following:

Initiator:	358 scrapped
Coldplate:	38 scrapped
Radiator panel:	12 scrapped

[redacted]

COMPONENT TECHNOLOGY

IN-HOUSE ACTIVITIES

Application Data

Tabulated charts have been prepared on those resistors, transistors, and diodes which reflect the current state-of-the-art in component quality and reliability. These charts utilize a system of headings and subheadings to direct attention to the desired part with a minimum of effort. (Table 7, on resistors, is an example.)

In order to avoid restricting the technical activities of the circuit designers, current Specification-Controlled Drawing (SCD) parts are, in some instances, being augmented with recommended commercial parts of known quality, produced by the latest processes, and available from well established manufacturers. Such commercial parts will, upon request, be converted to SCD-controlled parts. The commercial numbers are listed on a tabulation to provide an orderly transition between the time of need for a new part and the inclusion of the part in the S&ID parts manual or preferred parts list.

Contamination Control

Technical assistance is being furnished Apollo GSE on the design of an air supply unit which will control temperature, humidity, and airborne particulate matter to the level of class 100,000 per Fed Std 209. The unit will provide a suitable environment within the service module during the interfacing of cleanliness-critical items.

SUBCONTRACTOR/SUPPLIER ACTIVITIES

Detergent Bomb Tests on Semi-Conductors

The detergent bomb tests specified in Minneapolis-Honeywell's semi-conductor specification for gross leak detection were suspected as being a latent cause of failure. Although an extensive investigation has failed either to support or deny this suspicion, the tests are being prohibited on deliverable semi-conductors. Parts subjected to this test have a proven failure rate of only 0.0004 percent per 1000 hours, so the replacement of assembled detergent bomb tested semi-conductors is not justified.

[redacted]

Table 7. Resistor Electrical Data Summary

TYPE PART NO.			ELECTRICAL DATA																	MECHANICAL DATA		F.R.	REMARKS
			RATINGS					3 YEAR WORST CASE RESISTANCE TOLERANCE - ± %														% / 1000 HRS 90% CONF.	
										0% POWER			50% POWER			100% POWER							
WATTS	% TOL.	ME 443-DASH NO.	RESISTANCE RANGE OHMS	θ TR °C/W	TC PPM/°C	FULL PWR °C	ZERO PWR °C	TC PPM/°C	3 YR ΔR %	-40 °C	25 °C	125 °C	-40 °C	25 °C	125 °C	-40 °C	25 °C	125 °C	L	D		
HIGH RELIABILITY RESISTORS - ESTABLISHED RELIABILITY - TRACEABLE BY LOTS - HIGHEST QUALITY STATE-OF-ART																							
METAL FILM - MOLDED OR CONFORMALLY COATED																							
1/8	1.0	0060	30.1 Ω to 499 K	45	25	125	170	25	1.0	2.16	2.00	2.25	2.10	2.05	2.30	2.04	2.11	2.36	0.375	0.125	0.01	Recommended for use in critical application in airborn systems. Good frequency characteristics up to 100 Mc. Very good stability.
1/4	1.0	0061	51.1 Ω to 1.00 M	45	25	125	170	25	1.0	2.16	2.00	2.25	2.10	2.05	2.30	2.04	2.11	2.36	0.625	0.188	0.01	
1/2	1.0	0062	51.1 Ω to 1.50 M	45	25	125	170	25	1.0	2.16	2.00	2.25	2.10	2.05	2.30	2.04	2.11	2.36	0.750	0.250	0.01	
1.0	1.0	0063	51.1 Ω to 3.92 M	45	25	125	170	25	1.0	2.16	2.00	2.25	2.10	2.05	2.30	2.04	2.11	2.36	1.063	0.375	0.01	
2.0	1.0	0064	51.1 Ω to 10.0 M	45	25	125	170	25	1.0	2.16	2.00	2.25	2.10	2.05	2.30	2.04	2.11	2.36	2.188	0.375	0.01	
METAL FILM - HERMETICALLY SEALED																							
1/8	1.0	0138	10.0 Ω to 200 K	50	100	125	175	100	0.5	2.15	1.50	2.50	1.90	1.75	2.75	1.64	2.00	3.00	0.281	0.155	0.01	Same as above
PRECISION WIREWOUND																							
1/8	0.1	0073	1.00 Ω to 100 K	20	15	125	145	15	0.2	0.39	0.29	0.44	0.38	0.31	0.46	0.36	0.32	0.47	0.310	0.250	0.005	Very good stability. Tight initial tolerance and low drift. Not recommended for use above 5.0 Kc.
1/4	0.1	0074	1.00 Ω to 1.00 M	20	15	125	145	15	0.2	0.39	0.29	0.44	0.38	0.31	0.46	0.36	0.32	0.47	0.500	0.250	0.005	
1/2	0.1	0127	1.00 Ω to 3.97 M	20	15	125	145	15	0.2	0.39	0.29	0.44	0.38	0.31	0.46	0.36	0.32	0.47	0.812	0.297	0.005	
1.0	0.1	0076	1.00 Ω to 4.99 M	20	15	125	145	15	0.2	0.39	0.29	0.44	0.38	0.31	0.46	0.36	0.32	0.47	1.000	0.500	0.005	
POWER WIREWOUND																							
2.0	1.0	0068	0.10 Ω to 16.2 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	0.810	0.187	0.1	Recommended for use in applications where very high body temperatures can be tolerated, and where relatively small physical size is desirable. * CHASSIS MOUNTED TYPES
5.0	1.0	0069	0.10 Ω to 11.8 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	0.880	0.312	0.1	
10.0	1.0	0107	1.00 Ω to 15.0 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	1.780	0.380	0.1	
10.0	1.0	0070*	1.00 Ω to 5.62 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	1.380	0.810	0.1	
25.0	1.0	0071*	1.00 Ω to 12.4 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	1.940	1.090	0.1	
50.0	1.0	0072*	1.00 Ω to 39.2 K	250	20	25	275	20	1.0	2.56	2.70	2.90	2.11	2.25	2.44	2.36	2.50	2.70	2.180	1.160	0.1	
GENERAL USAGE RESISTORS - NON-CRITICAL APPLICATION - NON-TRACEABLE - ECONOMY TYPES																							
CARBON COMPOSITION (INSULATED)																							
1/4	5.0	0109	2.7 Ω to 22 M	80	2000	70	150	2000	8.0	26.0	13.0	33.0	18.0	21.0	41.0	16.0	29.0	49.0	0.250	0.090	- - - -	Not recommended for use where a drift in the order of 25% to 35% cannot be tolerated. These units will not open or short.
1/2	5.0	0110	2.7 Ω to 22 M	80	2000	70	150	2000	8.0	26.0	13.0	33.0	18.0	21.0	41.0	16.0	29.0	49.0	0.375	0.140	- - - -	
1.0	5.0	0111	2.7 Ω to 22 M	80	2000	70	150	2000	8.0	26.0	13.0	33.0	18.0	21.0	41.0	16.0	29.0	49.0	0.562	0.225	- - - -	
2.0	5.0	0112	10 Ω to 22 M	80	2000	70	150	2000	8.0	26.0	13.0	33.0	18.0	21.0	41.0	16.0	29.0	49.0	0.688	0.312	- - - -	
CARBON FILM - SEALED																							
1/8	1.0	0079	5.11 Ω to 1.00 M	95	-500	70	165	-500	1.0	5.25	2.00	7.00	2.87	4.37	9.37	3.50	6.75	11.75	0.375	0.125	- - - -	Not recommended for critical application. Good frequency characteristics up to 100 Mc. Fairly good stability.
1/4	1.0	0080	10.0 Ω to 2.00 M	95	-500	70	165	-500	1.0	5.25	2.00	7.00	2.87	4.37	9.37	3.50	6.75	11.75	0.625	0.188	- - - -	
1/2	1.0	0081	10.0 Ω to 4.99 M	95	-500	70	165	-500	1.0	5.25	2.00	7.00	2.87	4.37	9.37	3.50	6.75	11.75	0.750	0.250	- - - -	
1.0	1.0	0082	10.0 Ω to 10.0 M	95	-500	70	165	-500	1.0	5.25	2.00	7.00	2.87	4.37	9.37	3.50	6.75	11.75	1.063	0.375	- - - -	
2.0	1.0	0083	30.1 Ω to 20.0 M	95	-500	70	165	-500	1.0	5.25	2.00	7.00	2.87	4.37	9.37	3.50	6.75	11.75	2.188	0.375	- - - -	
PRECISION WIREWOUND																							
1/8	0.1	0098	1.00 Ω to 100 K	20	30	125	145	30	0.5	0.79	0.59	0.89	0.76	0.62	0.92	0.73	0.65	0.95	0.310	0.250	- - - -	Not recommended for critical applications. See remarks for PRECISION WIREWOUND (above)
1/4	0.1	0099	1.00 Ω to 1.00 M	20	30	125	145	30	0.5	0.79	0.59	0.89	0.76	0.62	0.92	0.73	0.65	0.95	0.500	0.250	- - - -	
1/3	0.1	0100	1.00 Ω to 2.00 M	20	30	125	145	30	0.5	0.79	0.59	0.89	0.76	0.62	0.92	0.73	0.65	0.95	0.750	0.250	- - - -	
1.0	0.1	0101	1.00 Ω to 4.99 M	20	30	125	145	30	0.5	0.79	0.59	0.89	0.76	0.62	0.92	0.73	0.65	0.95	1.000	0.500	- - - -	
POWER WIREWOUND																							
2.0	1.0	0093	0.10 Ω to 39.2 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.18	2.37	2.67	2.55	2.75	3.05	0.810	0.187	- - - -	Not recommended for critical applications. See remarks for POWER WIREWOUND (above). * CHASSIS MOUNTED TYPES
5.0	1.0	0094	0.10 Ω to 75.0 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.18	2.37	2.67	2.55	2.75	3.05	0.880	0.312	- - - -	
10.0	1.0	0108	0.10 Ω to 240 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.18	2.37	2.67	2.55	2.75	3.05	1.780	0.380	- - - -	
10.0	1.0	0095*	0.10 Ω to 34.8 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.18	2.37	2.67	2.55	2.75	3.05	1.380	0.810	- - - -	
25.0	1.0	0096*	0.10 Ω to 75.0 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.19	2.37	2.67	2.55	2.75	3.05	1.940	1.090	- - - -	
50.0	1.0	0097*	0.10 Ω to 237 K	250	30	25	275	30	1.0	2.19	2.00	2.29	2.19	2.37	2.67	2.55	2.75	3.05	2.180	1.160	- - - -	

FOR FURTHER INFORMATION: CONTACT NORM WILLIAMS, S&ID, DOWNEY, BLDG. 5, EXT. 3755/3756

No. 1 May 64

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CDC Specification Review

During a review of Control Data Corporation (CDC) specification test requirements, it was observed that the price of some piece parts had significantly increased above original estimates. The price break-down submitted by CDC demonstrated that the high cost was generated, in some cases, by configuration and quality assurance tests. (Parts in question included transistors, resistors, diodes, and relays.) Apollo Material, Reliability, and Engineering are reviewing the entire pricing structure used by CDC for piece parts. This activity includes the investigation of other sources and a reexamination of test requirements to effect significant economies without jeopardizing quality or reliability.

PROCUREMENT SPECIFICATIONS

Relays

The high-reliability relay specification, MC455-0025, and related SCD's are being evaluated for the purpose of reducing the costs of qualification and acceptance tests without a loss of reliability. The feasibility of using the results of tests by other qualified users as a qualification instrument is also being investigated.

Connectors

In cooperation with Apollo Standards, a specification covering preferred subminiature connectors (MC414-0426) is being developed. One connector type covered by this specification will replace the Hughes connector currently being used in the Apollo program. This specification has been released to Purchasing, which has submitted bid packages to potential suppliers. Prospective suppliers were requested to submit copies of previous qualification or test data on equivalent designs as possible evidence of qualification by similarity.

Integrated Circuits

A procurement specification and three associated SCD's, covering five integrated circuit networks for Apollo divided-power systems, have been released. These documents reflect requirements which will prevent the solder ball problems experienced by Elgin on integrated circuitry procured from Texas Instruments.

Parts Protection

MA0116-027, "Intra/Inter Plant Parts Protection, Requirements for High Reliability Items," has been revised to clarify some of the receiving and storage requirements and reflect latest practices in this area.

The first parts covered by a high-reliability specification (diodes, ME479-0093) were issued during the report period for use in the command module.

RELIABILITY ASSESSMENT

ASSESSMENT STATUS

The reliability assessments presented in Table 8 include, in addition to the numerics, brief references to the techniques by which the assessments were made and comments on the significance of the numerics and the reliability goals. More detailed information and data can be found in the referenced documents. The assessments are of equipment reliability and not of overall mission success, which would have to include the reliability of logistics, usage, etc.

ASSESSMENT PHILOSOPHY

Reliability assessments of Apollo equipment are computed at the most meaningful level. When sufficient test information is available at the system level, it is used for the assessment. If system data are unavailable or inadequate, data at lower levels of assembly are evaluated and use to obtain reliability numerics for lower level components. When interactions are not significant and data are available for all major lower-level components, the numerics are combined to obtain system reliabilities. However, if interaction effects cannot be determined, this combination is not attempted. A primary criterion for the inclusion of assessment data is that the equipment must be substantiated through its development phase. If development is still in progress and the design is subject to modification or change, an assessment is not made.

Data are evaluated by the most applicable statistical techniques. Variables methods (parameter variations) are used wherever possible because they provide higher confidence levels from the same amount of data than do attribute methods (go/no-go). The variables methods employ techniques for one- and two-sided specification limits with established methods and statistical tables, correlation and regression analyses, and stress-strength safety margin evaluations. In addition, the binomial method was employed to evaluate attribute data. Other variables and attributes methods are available and will be utilized when the nature of the data requires them.

Reliability assessment numerics are provided at the sixty- and ninety-percent levels of confidence. These levels were chosen as being the most desirable from both the numerical and analytical standpoints. The sixty-percent level provides a somewhat better assurance than the fifty-fifty

[redacted]

Table 8. Reliability Assessment Status

Part No.	Name	Criticality	Test Phase	Reliability Assessment Technique and References	Items Evaluated	Cumulative Statistical Failures	No. of Trials	Mission Requirement	Reliability Objective	Reliability Status at Confidence Level 60%	Reliability Status at Confidence Level 90%	Reliability Significance
ME 467-0003	Launch escape motor	I (man) II (unman)	Development (completed March 1964)	Assessment by characteristics: binomial, safety margin, correlation, and performance variables, as applicable (AP 64-242, LPC 588-P-1 to -28). Worst-case for dependent parameters.	22 (18*)	0	22 firings	1 shot and specific limits	0.998	0.983	0.952	First reliability assessment indicates a close relationship to the reliability objective. Average thrust, the primary factor influencing the assessment numeric, requires further engineering definition.
ME 467-0001	Tower jettison motor	I (man) II (unman)	Qualification (17 firings remaining)	Assessment by variables data of specification performance parameters. Binomial distribution for probability of ignition. Worst-case for dependent parameters used in parameter numerical estimates.	24 (22*)	1**	24 firings	1 shot and specific limits	0.99995	0.980	0.957	Initial assessment of the development program test data indicates a favorable relationship in the achievement of reliability objective. Resultant total impulse, the primary factor influencing the assessment numeric, requires further engineering definition.
ME 901-0001	Earth landing subsystem	I	Development (in process)	Assessment based upon binomial probability distribution of main stream end-item configuration and system tests.	13	0***	13 tests	1 operating cycle	0.99994	0.932	0.838	Based upon N-V main stream effort of end-item configuration and system tests.
ME 453-0014, 0081, 0082, and -0008	Igniter cartridges	III	Development (completed)	Binomial probability function to assess success/failure device. (Reliability status is estimate for one igniter cartridge.)	159	0	159 firings	1 shot	0.999	0.991	0.985	No "failure to fire" occurred, but five cartridges exceeded maximum specification requirement. Assessment based upon variables data of peak pressures from lot acceptance firing tests. Closer parameter control recommended.

*Dependent upon parameters analyzed
**Not used for assessment purposes
***The recommendations presented in SID 63-1201, as a result of the loss of Boilerplate 3, have been incorporated. This failure was carried for one year and is now removed from statistical considerations.

[redacted]

probability, and follows the practice of the Minuteman and other high-reliability programs. The ninety-percent level yields a high degree of confidence in the corresponding reliability numeric. (Assessments at this level are provided for information only.) However, when only a small amount of data is available, high confidence levels result in unrealistically low assessments.

II. ELECTRONIC SUBSYSTEM ANALYSIS

COMMUNICATIONS AND DATA

SUMMARY

During the past quarter, the Block I - Block II concept was introduced. This, combined with the cost reduction effort, has caused major modifications in the S&ID and the subcontractor reliability programs. Effort has been expended, taking full advantage of the required redesigns, to enhance the reliability of each Block II equipment configuration, while Block I equipment requirements and objectives have been modified to reflect the Block I mission objectives rather than those of the LOR mission.

ANALYSIS

PCM Telemetry Redundancy Level Analysis

An analysis was conducted to determine the optimum redundant configuration for the Block II PCM telemetry equipment. Three levels of redundancy were considered for both switchable and operationally redundant configurations: circuit, module, and module group.

The module group redundancy level was determined to be optimum. Recommendations concerning the implementation of this redundancy are forthcoming.

S-Band Power Amplifier Study

The results of a failure effects analysis indicated that a failure of any one of six diodes in the S-band power amplifier would actuate a circuit breaker in the +28-vdc line and render the data storage equipment, signal conditioning equipment, S-band power amplifier, and up-data discriminators in the premodulation processor inoperable. Further analysis indicated that the failure of any one of four of these six diodes could result in the actuation of the circuit breaker. However, the circuit breaker can only be actuated on a switching operation by the astronaut and can be reset once the switch has been returned to the original position. The failure of any one of these four diodes would then result in a partial loss of the S-band power amplifier, but would not result in the permanent loss of the other communication and data equipment.

The failure of the other two diodes could result in a partial loss of the S-band power amplifier, but a second failure would be required to actuate the circuit breaker. Therefore, no design changes were recommended by Apollo Reliability.

Signal Conditioner Current Limiter Study

The signal conditioning equipment power supply provides plus and minus 20-volt power to each of 38 modules within the equipment. A short in either of these power inputs in any one module would short that particular output of the power supply, and this loss of power to the other modules would render the signal conditioning equipment inoperable.

The results of a study to determine the existence of such a failure mode indicated that in only one module type, the ac-to-dc converter, is there a situation where a single failure would short the power input. Since the probability of the complete signal conditioning equipment failing due to a single failure within the ac-to-dc converter module is higher than the probability of an ac-to-dc converter module failing due to a current limiter failure, and based on the relative severity of a complete signal conditioning equipment failure compared to one module failure, the installation of current limiting devices only in the ac-to-dc converter modules was recommended.

SUBCONTRACTOR MANAGEMENT

Subcontractor Coordination

As a result of the Block I - Block II concept and the reduction in the effort allocated for fiscal year 1965, the reliability program of the subcontractor has been modified, including stopping work on parameter variation analyses, off-limit testing, and part application testing. The Block II reliability program is currently being defined to the subcontractor as a result of recent NASA-S&ID agreements on the nature and priority of reliability tasks to be performed.

Modifications to NAA environmental and qualification test requirements for subcontractors and suppliers have been initiated to conform with MCR-A619, Revision 2, Revised CM Crew Compartment Environmental Design Criteria. The specified humidity, oxygen, corrosive contaminants, environmental design, and test requirements have been added, and the number of units to be subjected to qualification testing has been reduced to two, per NASA-S&ID agreement. Meetings have been scheduled between NASA and S&ID to establish agreements regarding off-limit testing and the number of mission simulation tests to be performed on communication and data equipment. The components to be used in Spacecraft 006, 009, and 011, however, will not be fully qualified to the new humidity requirements.

Review of acceptance test procedures and data sheets for D-models has been completed, and these documents have been approved. Qualification test procedures and data sheets for the VHF multiplexer equipment and the data storage equipment have been received from the subcontractor.

With an NAA representative observing, the subcontractor conducted a trial design proof vibration test of the VHF multiplexer equipment. A sample test report was reviewed to determine the vibration test philosophy being followed by the subcontractor. The subcontractor has been instructed to submit more extensive information on vibration test fixtures and monitoring procedures.

Subcontractor Activities

The status of the subcontractor's reliability effort associated with the communications and data subsystem is summarized below.

Failure Mode Effect Analysis (FMEA)

The present status of the FMEA program is shown in Table 9.

Table 9. Communications and Data Subsystem FMEA Program Status

Equipment	Latest Revision	Configuration (Model)
Audio center	1-16-64	E
HF transceiver	3-1-64	D
Premodulation processor	10-4-63	E
S-band power amplifier	11-29-63	E
Signal conditioner	7-15-64	D
VHF-AM transmitter-receiver	7-15-64	D
VHF-FM transmitter	1-6-64	E
VHF receiver beacon	1-16-64	E
VHF multiplexer	12-15-63	E
Unified S-band equipment	5-29-63	E
PCM telemetry equipment	1-31-64	E
C-band transponder	4-17-64	E
Data storage equipment	5-31-63	E

[redacted]

Parameter Variation Analysis

As agreed upon with NASA, all parameter variation analysis effort has been stopped for manpower reduction purposes. All data, along with a comprehensive rough draft status report, have been filed in a central location for ease of restarting the project at some future date.

RELIABILITY PREDICTIONS

A tabular summary of current equipment reliability predictions for the communications and data subsystem is presented in Table 10.

Table 10. Equipment Reliability Prediction Summary

Equipment	Apportionment	Prediction
Signal Conditioning Equipment		
Phase sensitive demodulator	0.99864	0.99856
Frequency sensitive demodulator	0.99853	0.99860
DC amplification	0.99858	0.99804*
DC attenuation	0.99894	0.99876*
AC-to-dc conversion	0.99861	0.99862*
10-vdc power	0.99954	0.99950
5-vdc power	0.99954	0.99950
HF transceiver	0.99972	0.99945
S-band power amplifier	0.9969	0.9979
Premodulation processor	0.9967	0.99375
Audio center	0.9969	0.9959
VHF-FM transmitter	0.99996	0.99982
VHF-AM transmitter-receiver	0.9990	0.99918
VHF recovery beacon	0.99981	0.99946
PCM telemetry equipment	0.9630	0.97756
C-band transponder	0.9995	0.9991
Data storage equipment	0.9930	0.99547
Unified S-band equipment	0.9954	0.9902
VHF multiplexer	None	

*Most complex circuit utilized

The advent of the Block I - Block II concept requires a reapportionment of the reliability objectives for Block II. The Block I apportionments in Table 10 were originally calculated for the LOR mission on the basis of the equipment operating times specified in MC 999-0023, General Specification for the Apollo Communications and Data Subsystems, and reflect worst-case electrical stresses. The original LOR apportionments for the communications and data subsystem are being used for the Block I apportionments. It is anticipated that LOR reliability objectives will be exceeded for Block I missions.

PLANNED ACTIVITIES

The next quarter will be devoted to defining the Block II equipment configurations and reliability constraints based upon Apollo system objectives. Specifics to be defined are the equipment reliability apportionments, the qualification test program, and the subcontractor's reliability program. Analysis will continue to assure attainment of the inherent reliability of the Block I equipment and optimization of the Block II equipment reliability capability.

GUIDANCE AND NAVIGATION

SUMMARY

Activities of the quarter were centered around the development of reliability logic diagrams for Block II. These logic diagrams, along with the necessary supporting data, will satisfy basic data requirements for the integrated guidance and control Block II apportionments study. Planned activities include a more extensive program for direct technical liaison with subcontractors and associate contractors to facilitate exchange of technical data and to provide orientation in the process of integrating subsystems into the overall spacecraft.

ANALYSIS

A brief report on the importance of accurately determining rendezvous radar antenna environments, as related to the reliability of CSM G&N functions during LEM excursion, was included in the Ninth Quarterly Reliability Status Report, SID 62-557-9. The following paragraphs are in response to a NASA/MSC request for more detailed information. They describe spacecraft environments which must be considered in the determination of high-reliability design requirements for the antenna equipment.

CSM Rendezvous Radar/Transponder Thermal Environments

A study was undertaken to determine the environmental design requirements for the command and service module rendezvous radar/transponder. Reliability evaluations associated with the analysis of the thermal variants extant as parameters of the antenna are subject to two basic constraints:

1. Thermal stresses must not exceed derating limit boundaries for the antenna functioning in either the passive or the active mode to assure the required probabilities of mission success and crew safety.

2. Thermal deviations from a preestablished value must be minimized to maintain the antenna boresight and tracking accuracies within tolerance limits.

Uneven heating rates on the supporting boom of the radar antenna will have a significant influence upon the attainment of required boresight accuracies. MIT/IL has indicated, as noted in the minutes of S&ID-MIT meeting

No. 86B, that a shift in boresight of 5 milliradians will cause a severe increase in fuel consumption during the rendezvous operations. Accurate determination of parameters of this nature will be of considerable importance in the spacecraft optimization studies.

At this point in the program, detailed design information on the rendezvous radar/transponder is not available to S&ID. Therefore, because predicted thermal responses of equipment are dependent upon the geometry (including shape and size), surface emmisivity, solar absorptivity, radiation characteristics, density, and location of the devices evaluated, data were assimilated in a format which facilitates actual computation of numerical temperature values. Verification of the selected reliability design levels is dependent upon the receipt by S&ID of detailed design data from the associate contractors or from their suppliers.

SM Interior Environments

Thermal requirements for equipment installed inside the service module were determined, in general, to be dependent upon the location of the equipment, their power dissipation, the spacecraft flight attitude, and the spacecraft attitude profile history. Nominal values for equipment considered have been predicted to vary in worst cases between -100 and +180 F. In the following list, expected thermal environmental values are shown for equipment in the service module in accordance with their approximate location:

Location	Maximum Temperature (F)	Minimum Temperature (F)
Upper bulkhead	180	-100
Bay I	180	-100
Bay II (inside edge at X-200)	180	-65

CSM Exterior Environments

Thermal environments of equipment operating on the exterior of the command and service modules are determined from evaluations of complex parameters. For example, the SPS and RCS engine firings are intermittent and create relatively high heating rates. In addition, thermal increments due to solar radiation, electronic equipment power dissipation, and the deep-space temperature of -460 F must be determined accurately in order for maximum and minimum thermal levels to be determined.

RCS Engine Induced Environments

Heat distribution data of the exhaust flow field of the service module reaction control subsystem engine are shown in Figure 5. As a result of this heat source, the CM rendezvous radar antenna will be exposed to convective, radiative, and a certain amount of conductive heating. The engine plume impinges upon the antenna. Methods of obtaining static pressure (P_s), static temperature (T_s), and flow direction relative to the plume centerline (ϕ) for the purpose of computing heating rates at different points within the plume are shown below. These evaluations are subject to the following conditions and assumptions:

1. The RCS plume enclosed is the flow field cross section that results from passing a plane through the centerline of the plume.

2. The plume is assumed to be axisymmetric so that the flow field cross section is identical for any plane passed through the centerline.

3. The plume enclosed shows the SM surface so that protuberances may be drawn and data points located. To obtain P_s, T_s, and ϕ for respective data points, locate the point to be evaluated on the plume drawing (Figure 5) and determine the mach number (M) and the flow direction (ϕ) by inspection. (The flow direction is the angle that the streamline at the data point makes with the plume centerline.) P_s and T_s are determined by Equations 1 and 2.

$$P_s = \left(\frac{P_t}{P_e}\right)(P_e)\left(\frac{P_s}{P_t}\right) \tag{1}$$

$$T_s = \left(\frac{T_t}{T_e}\right)(T_e)\left(\frac{T_s}{T_t}\right) \tag{2}$$

The ratios P_t/P_e and T_t/T_e and the values P_e and T_e are obtained from the special data noted on Figure 5. The ratios P_s/P_t and T_s/T_t are obtained from an isentropic flow table for the mach number at the data point selected and for a gamma (γ_e) of 1.315. (Gamma represents the ratio of the specific heats.)

Dynamic stresses are obtained from the Newtonian impact equation, as follows:

$$P_n = (1 + \alpha M_1{}^2 \, \mathrm{Sin}^2 \, \alpha) \, P_s \tag{3}$$

where

P_n = Dynamic pressure

P_s = Static pressure existent prior to impingement-induced forces

M_1 = Mach number at the point of investigation

α = Angle between the streamline, at the data point evaluated on Figure 5, and the impinged surface

An additional dynamic factor to be considered involves the temperature within the compressed envelope of the initial shock wave boundary layer which is formed slightly above the impinged surface. The temperature within this envelope is much greater than the temperature of the impinging jet stream, and it varies in direct proportion to the radiation coefficient of the products of combustion which are entrapped within the envelope of compression. In view of the fact that water vapor and carbon dioxide have the highest radiation coefficients, and because their concentration is high in the SM RCS engine exhaust, these species represent the greatest offenders in this case. The gas composition of the SM RCS exhaust is given in the following list:

Species		Mole Fraction
H		0.03159
OH		0.01678
CO		0.05097
CO_2		0.07426
H_2		0.06164
H_2O		0.39936
NO		0.00694
N_2		0.34008
O		0.01329
O_2		0.00509
	Total	1.00000

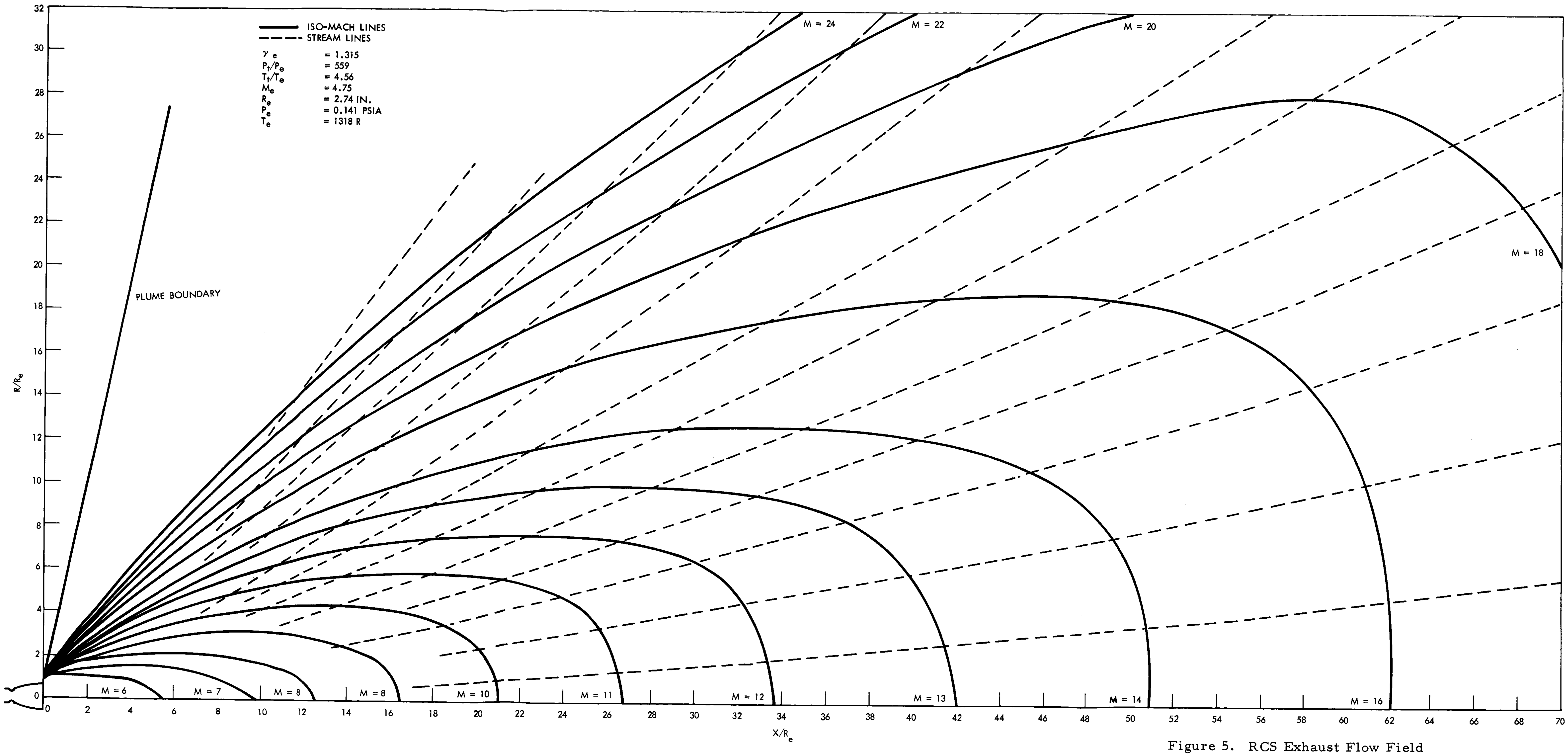

Figure 5. RCS Exhaust Flow Field

SM SPS Engine Induced Environments

The SM SPS engine plume does not impinge directly upon the rendezvous radar antenna. Thermal increments from this source are due basically to radiation and convection. As a general treatment, radiation-induced parameters are determined from two sources: the SPS external nozzle heat flux during engine firing and radiation from the heat flow field of the SPS engine exhaust. Figure 6 gives the radiation profile for the SPS nozzle. With the equations previously shown for the RCS motors, the influences due to the exhaust heat flow field can be determined from the isomach and isostream line curves and from the data on Figure 7. Convective increments are attributed to the effects of nonreal gas flow at the nozzle boundary layer and depend upon the influence that these gasses have upon the rendezvous radar antenna heating problem. Definite information in this area is not available at this time.

Solar Radiation

Temperatures resultant from solar radiation may be determined as a function of the ratio of solar absorptivity (A_s) to the antenna surface emissivity ratio (E). A curve showing the variance of temperature with this ratio is shown on Figure 8.

Heat Losses

Because S&ID had not received the detailed design data necessary for the computation of numerical values, thermal analyses were conducted upon typical antenna configurations to obtain best estimates of expected values.

Figure 9 shows the decrease in temperature with respect to time of a parabolic dish antenna once the heat sources have been removed and the antenna is subjected to the environment of deep space. These curves are drawn for a parabolic dish antenna, matching as closely as possible the design requirements of the rendezvous radar antenna, constructed of Rene 41, and having a surface emissivity (E) of 0.6. Figure 10 shows curves of a similar nature for a parabolic dish antenna constructed of stainless steel with an emissivity (E) of 0.3.

Heat Gains

To determine an approximate maximum (worst-case) temperature to be expected for the rendezvous radar antenna in the active or operating mode, an analysis was made of a typical parabolic dish antenna located at station X_s = 196 on the exterior surface of the service module. Results of the analysis are shown by the curves on Figure 11. The curves indicate the

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	1	2	3	4	5	6	7
HEAT FLUX (BTU/HR-FT^2)	75,000	54,000	27,500	17,500	14,000	12,500	8,900
TEMPERATURE (F)	2400	2160	1754	1539	1412	1363	1211
AREA RATIO (A_i/A_t)	6.0	11.6	21.5	30.9	40.5	49.3	57.5
LOCATION (IN.)	178.50	170.75	155.25	140.50	125.75	111.00	96.25

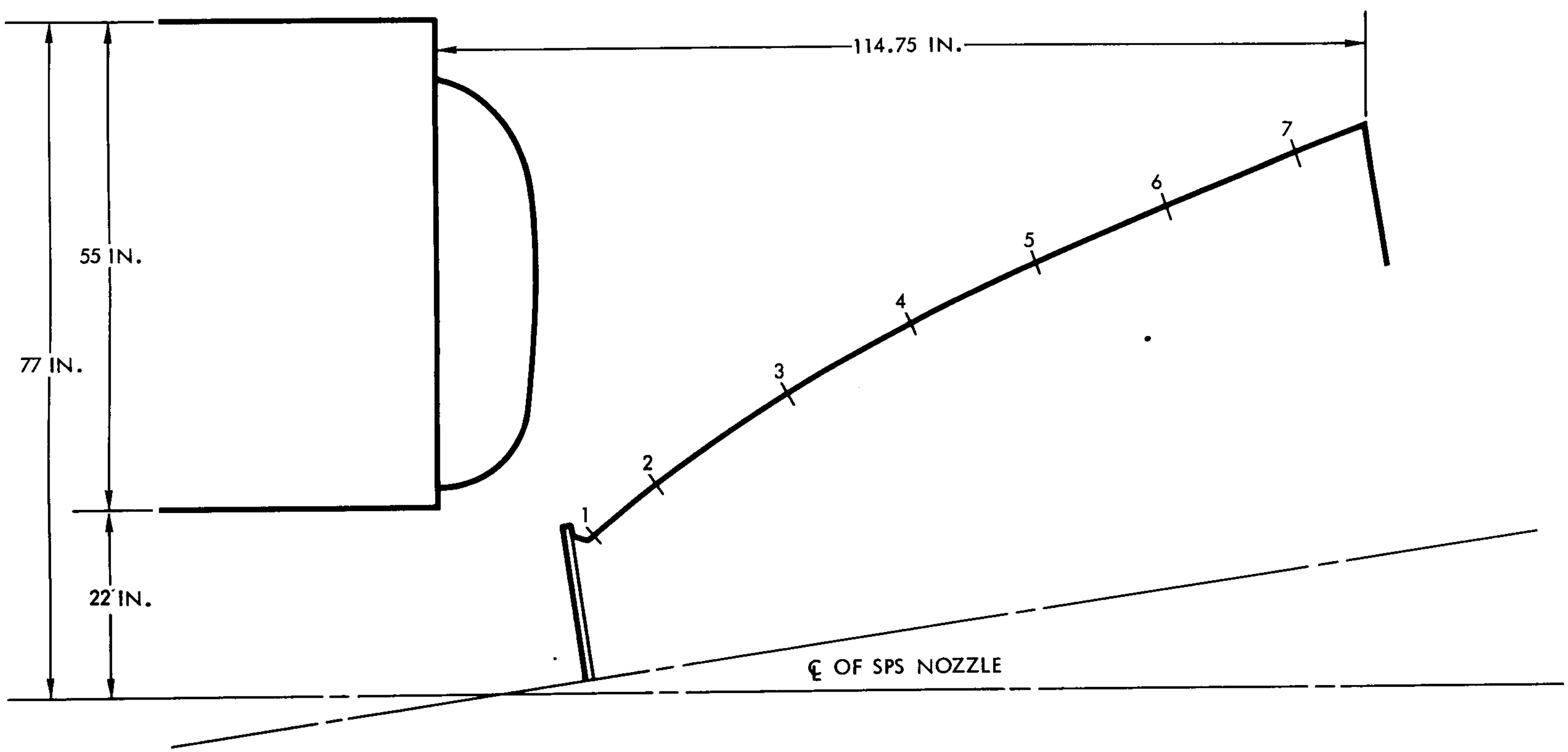

Figure 6. SPS Nozzle Heat Flux During Engine Firing

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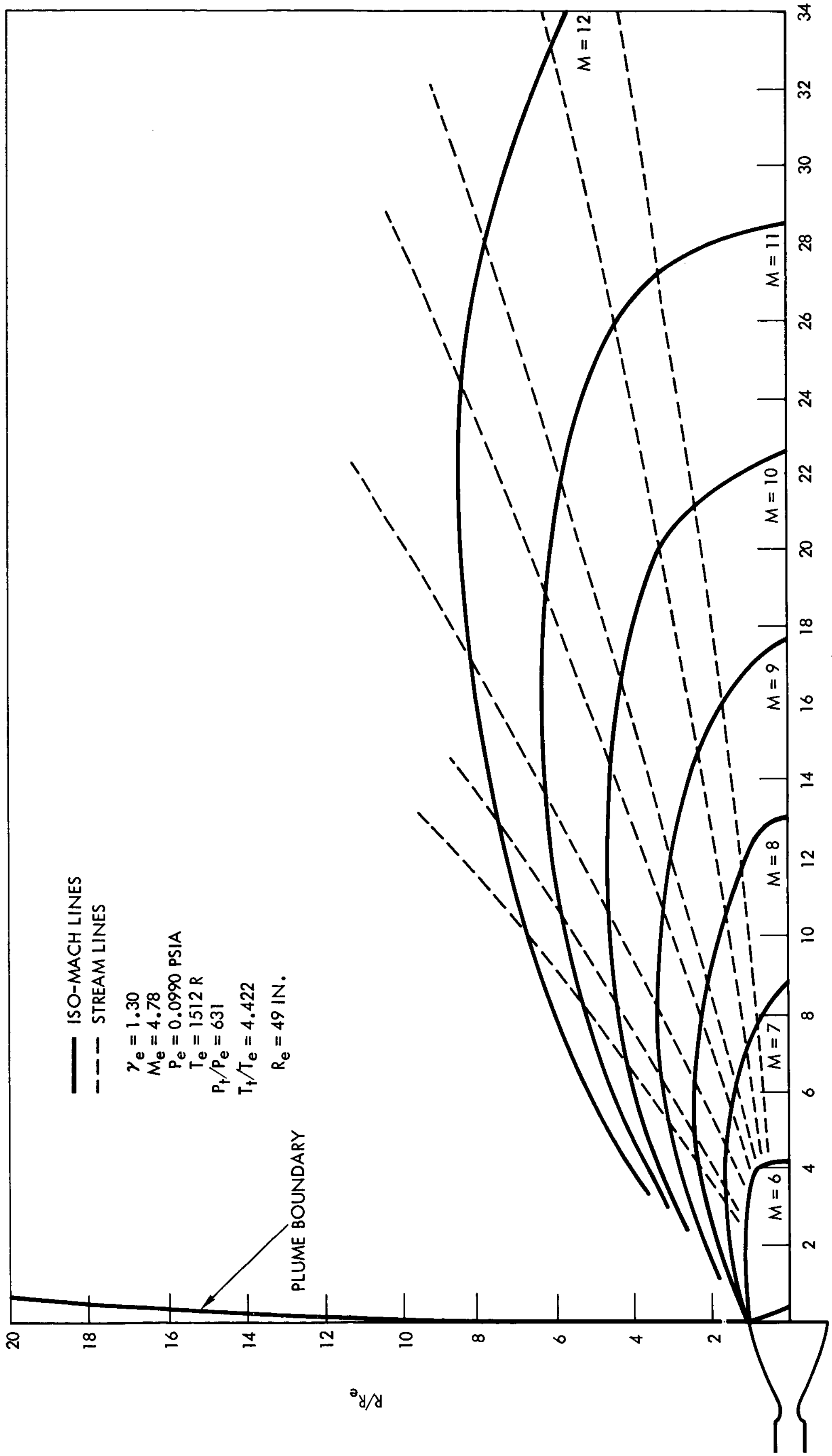

Figure 7. SPS Exhaust Flow Field

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[redacted] [redacted]

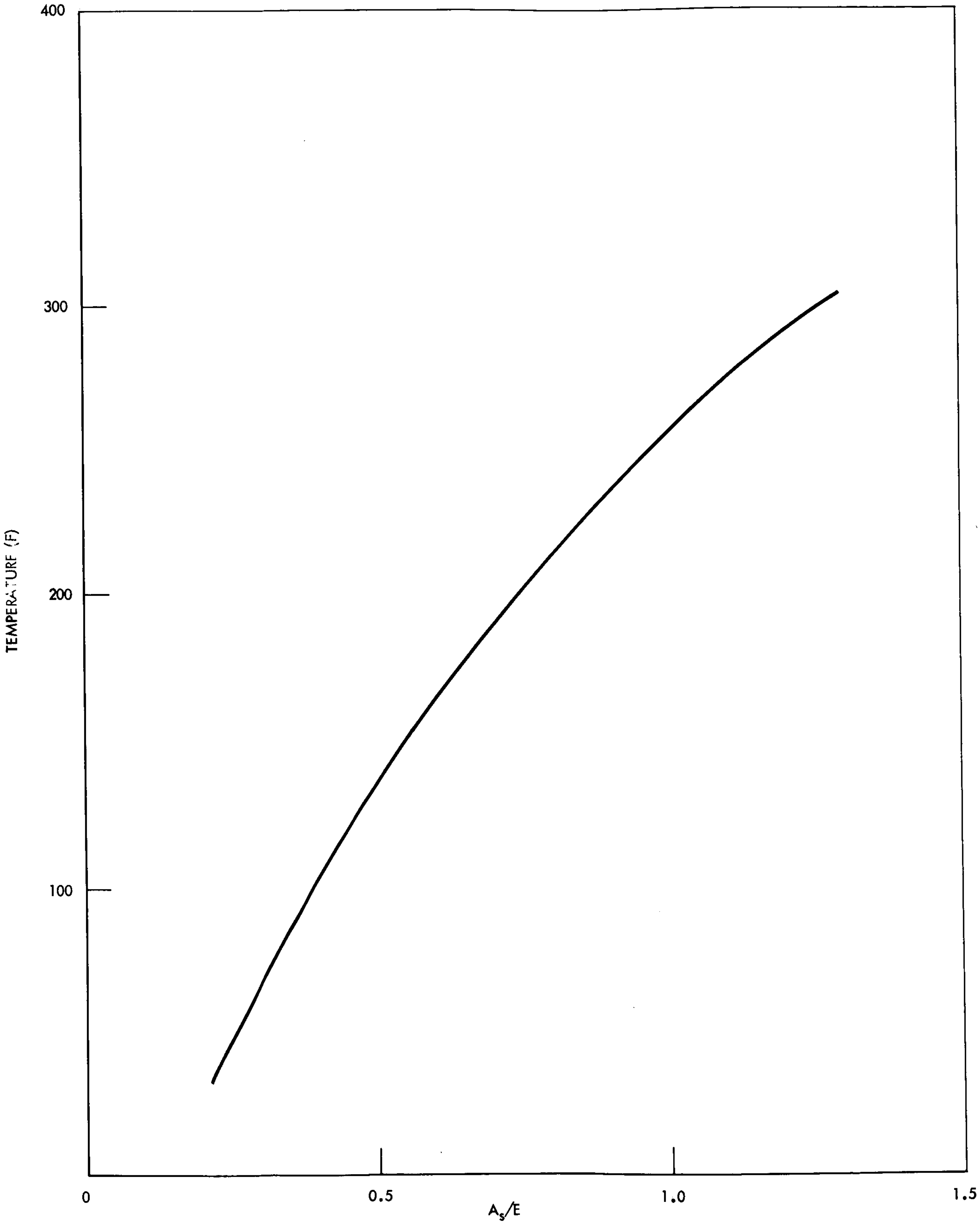

Figure 8. Rendezvous Radar Antenna Temperature as a Function of Solar Radiation

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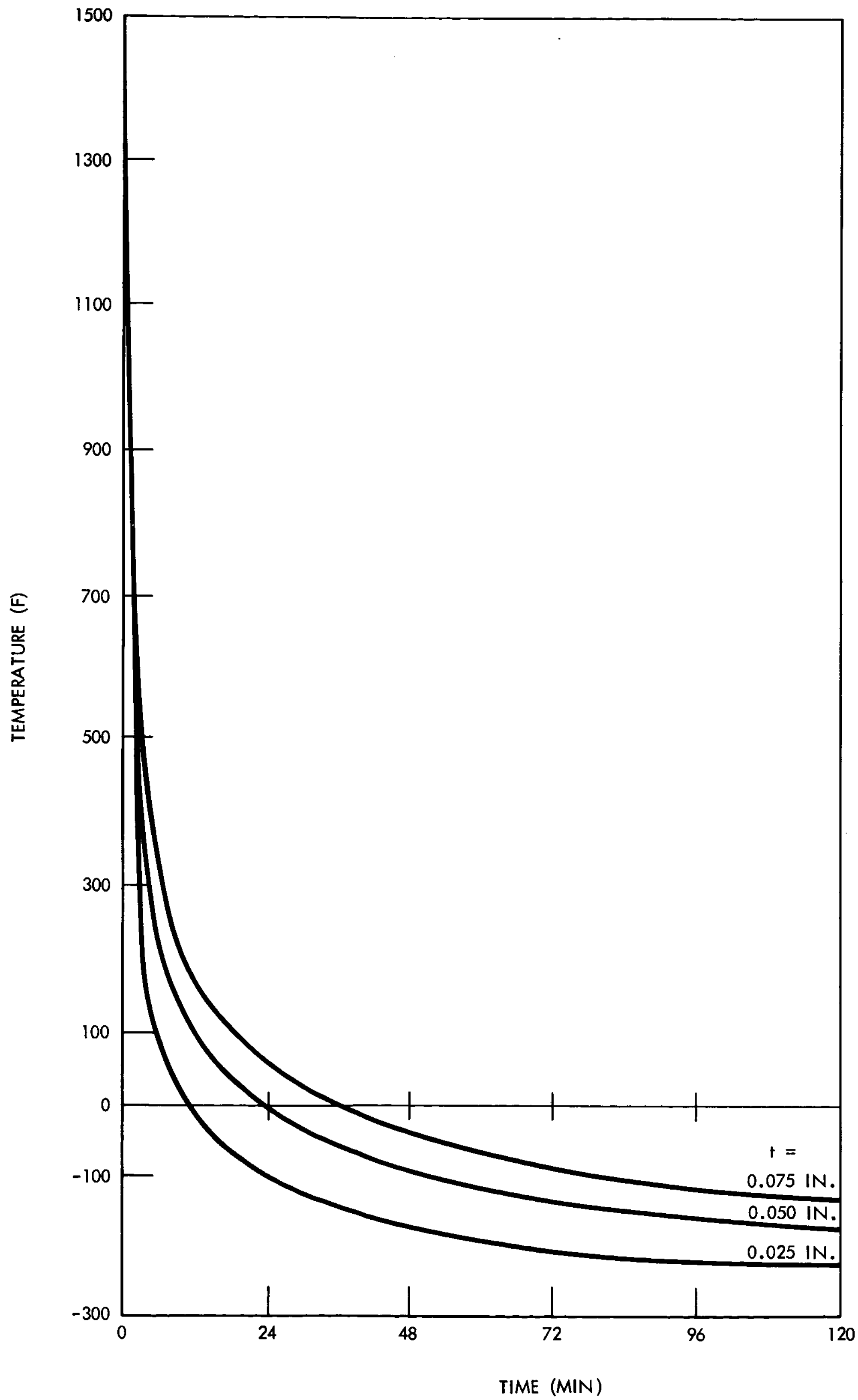

Figure 9. Parabolic Dish Antenna Temperature Decay Upon Removal of Heat Sources, E = 0.6

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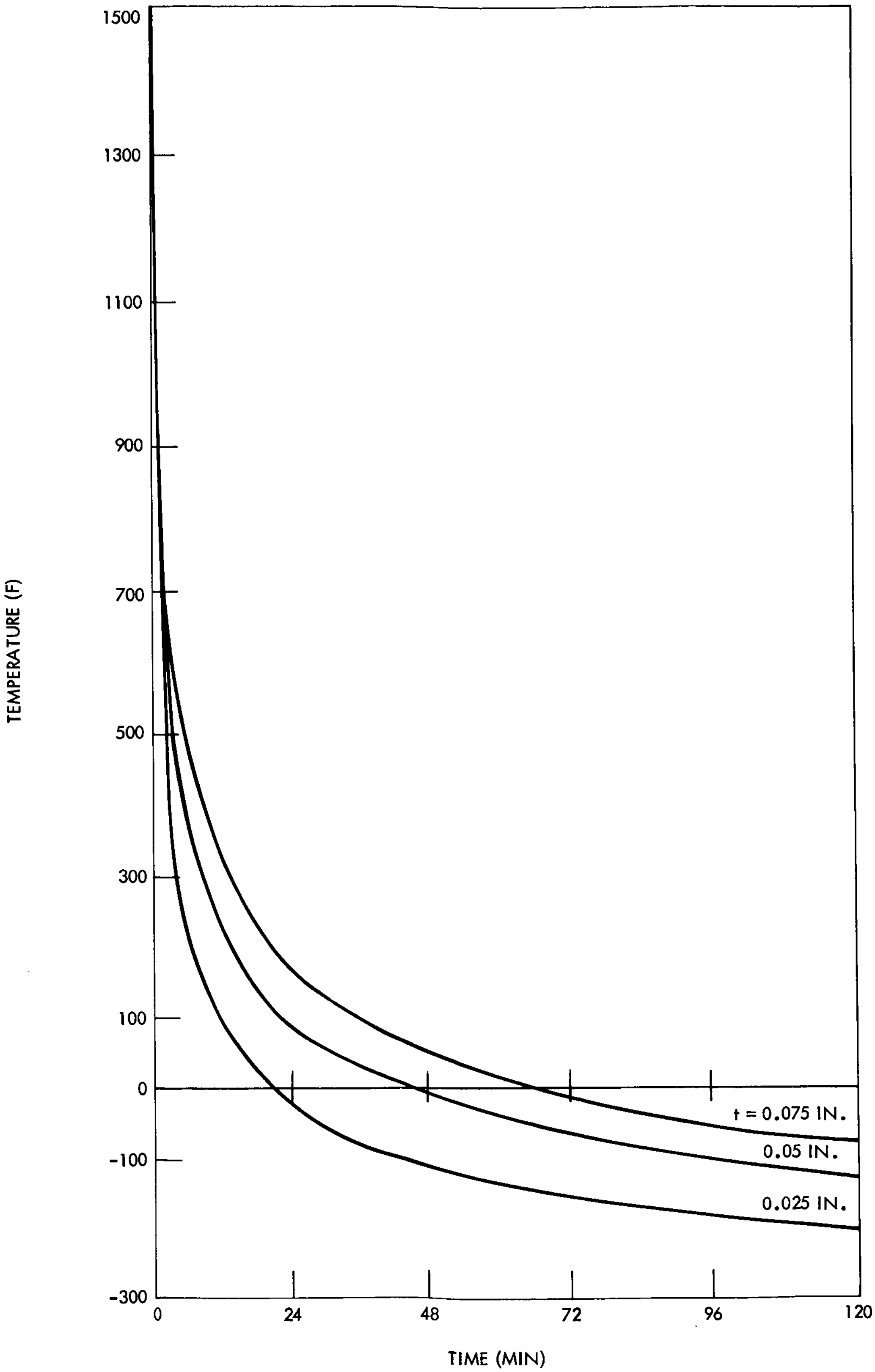

Figure 10. Parabolic Dish Antenna Temperature Decay Upon Removal of Heat Sources, E = 0.3

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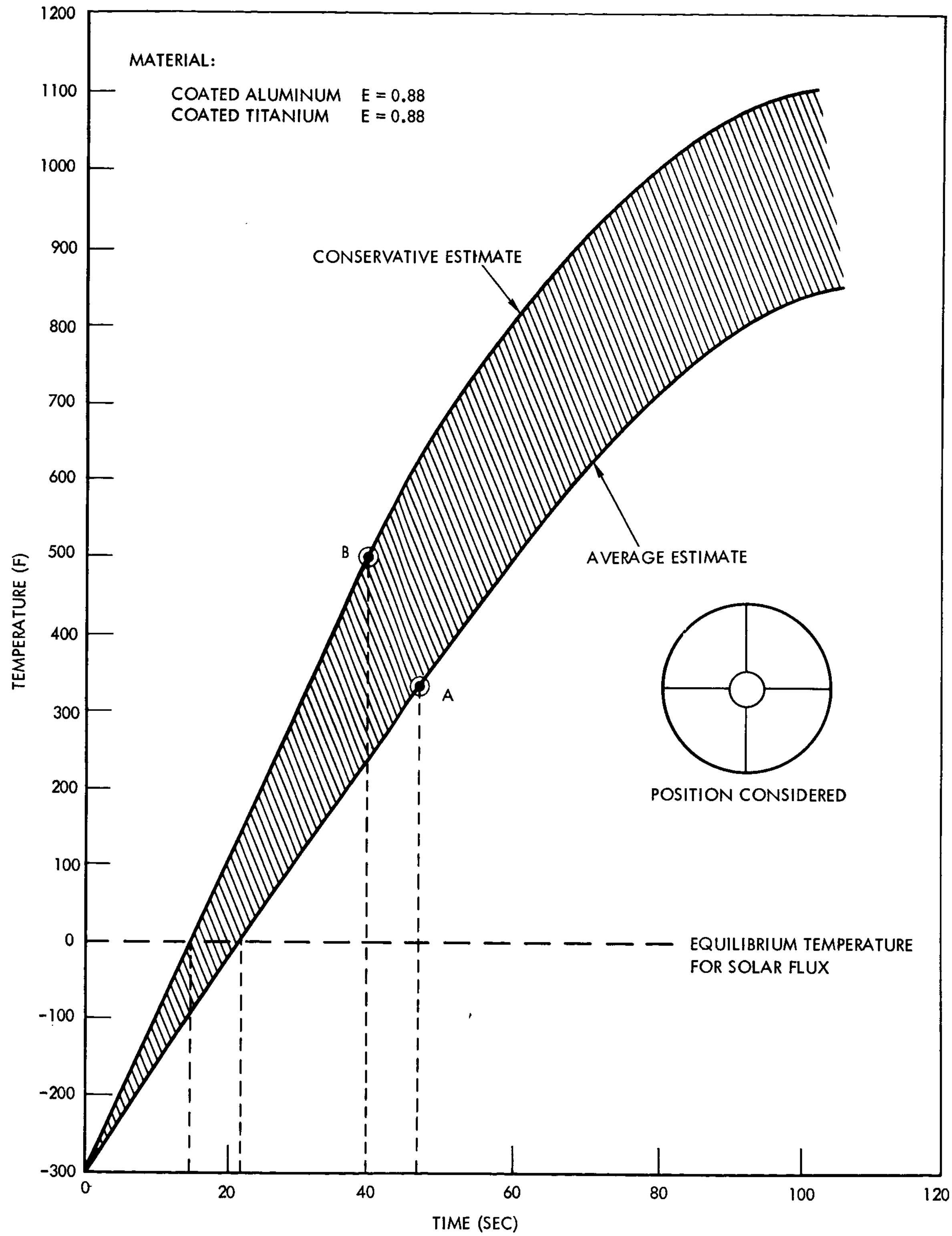

Figure 11. Temperature History of Rendezvous Radar Antenna at Station X_s = 196

variation of antenna temperature versus the burning time of four RCS engines firing simultaneously in a -X axis direction. Two engines that are considered to dominate the heat flow field are separated by 90 degrees with the antenna midway between them. The assumption of equal emissivity for the aluminum and titanium antenna is based upon a statement by GAEC that a special coating applied to either material will yield the emissivity value of E = 0.88.

Two curves are shown on the graph: the average estimate and the conservative estimate. The average estimate is obtained from the preliminary data used to perform the analysis. The conservative estimate is derived from values expected to be obtained with the acquisition of more accurate data. The points A at 350 F and B at 500 F represent approximate worst-case temperatures due to RCS engine firings. The RCS engine burning time was selected from Table 2-3 of the Tenth Quarterly Reliability Status Report, SID 62-557-10. The values shown on this curve are dependent upon a temperature rise from an equilibrium temperature for solar flux of 0 F. More refined analyses, anticipated as the program develops, will require a knowledge of the antenna heat soak factor resulting from midcourse and terminal rendezvous corrections which must be made along the command and service module LEM retrieval trajectory.

Variant heating effects upon the rendezvous radar transponder antenna and the exterior elements of the guidance and control scanning telescope and sextant will have to be determined by the methods that have been pointed out for the rendezvous radar antenna. Figure 12, representing a temperature history of the CSM rendezvous radar/transponder antennas during the boost phase, shows maximum temperatures of 400 and 360 F for the aluminum wave guide and the Teflon window, respectively. These values may be compared with those obtained throughout the flight profile to determine worst-case conditions.

This study emphasizes one of the areas in which the variance between reliability and performance requires careful examination. Requirements for passive thermal control and optimum coverage of both spacecraft by GOSS communications during LEM excursion will influence final mission success and crew safety probability values.

S&ID - MIT Performance and Interface Requirements Specification

Reliability inputs for the revised issue of SID 62-1000 were completed. Reliability design, test, and environmental requirements necessary to assure specified probabilities of mission success and crew safety for Block I configurations were included in this document.

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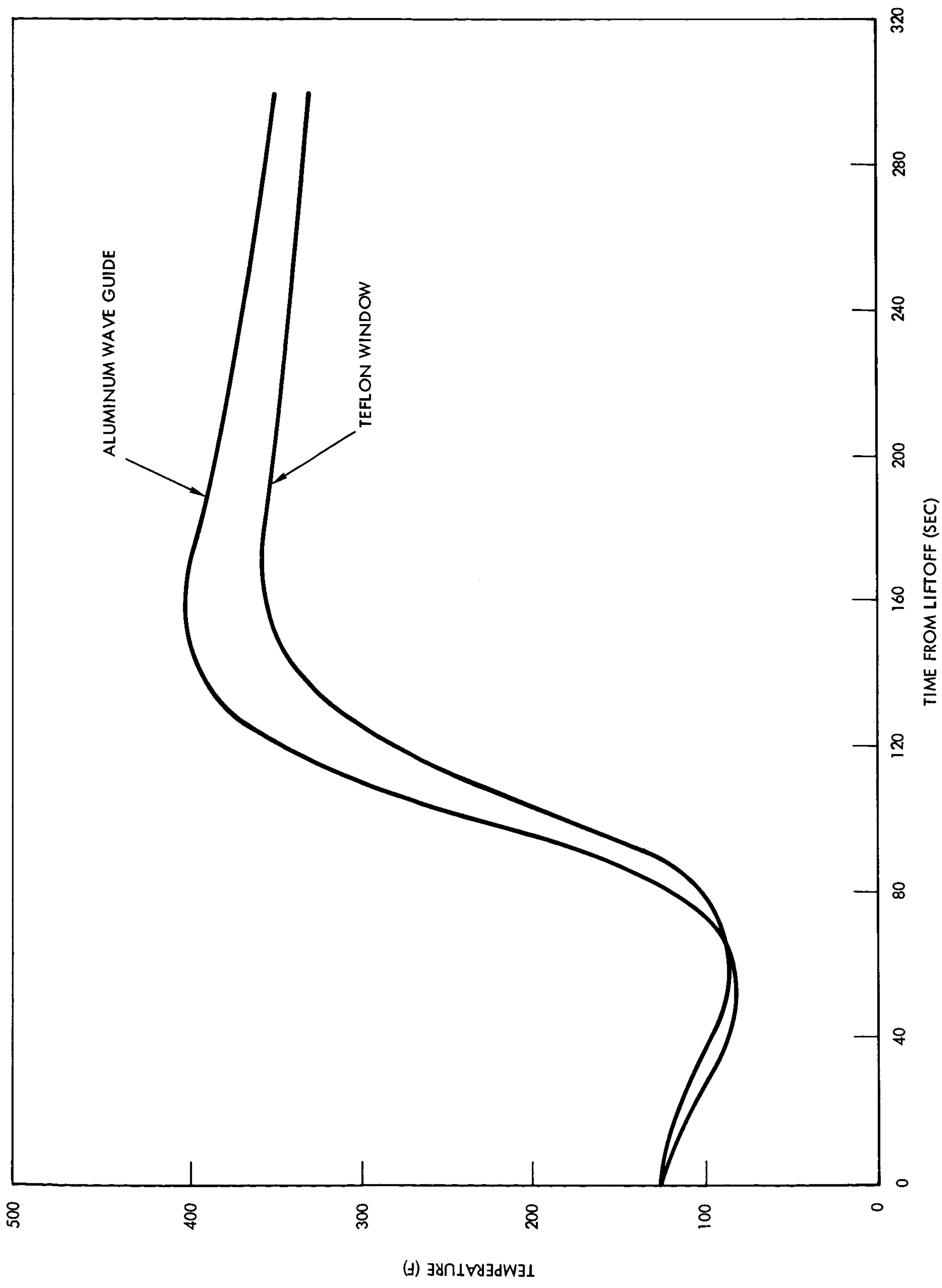

Figure 12. Temperature History of X-Band Beacon Antenna During Boost Phase

[redacted]

Block II Integrated Guidance and Control Activities

Guidance, navigation, and control inputs were completed for the integrated electronic subsystems reliability logic diagrams for Block II configurations. The task included the delineation of equipment necessary to perform primary modes of operation as well as the description of interfaces between guidance, navigation, and control equipment and interrelated equipment of other electronic subsystems of the spacecraft. Alternate paths of operation were formulated in which components of the guidance, navigation, and control subsystem were used with components of other subsystems to perform required time- and phase-oriented mission guidance and control functions. Particular care was exercised in the selection of paths, so that resultant configurations would represent the most effective combinations of equipment attainable. This procedure was followed to support the needs of optimization as related to total spacecraft functions. Reviews were performed of guidance, navigation, and control crew tasks as associated with Block II equipment, mission trajectories, and mission profile time lines to determine expected values for equipment operating time or duty cycles. Predicted failure rates of equipment were updated with the latest data received from associate contractors. Failure rate estimates were made of of new interface equipment required to fulfill the complement of integrated guidance and control functions. These data were assimilated and submitted to the Integrated Systems group for the mathematical and statistical model, which is being employed in current S&ID Block II apportionment studies.

LEM Interfaces

Guidance, navigation, and control inputs were completed for the integrated electronics subsystems reliability logic diagrams for the CSM rendezvous radar/transponder as related to functions of the lunar excursion module. Supporting data, similar to that acquired for MIT/IL-furnished guidance and control equipment, were obtained from both MIT/IL and GAEC for the apportionments study. Analyses were made of interfaces between guidance, navigation, and control functions and the rendezvous radar/ transponder to determine the requirements of optical equipment for in-flight boresight checkout of the rendezvous radar antenna.

Evaluations were made of the manned space flight network tracking functions to be provided during lunar excursion mission phases. These studies were performed to determine the equipment, the necessary paths of operation, and the limits of applicability for the GOSS control of cislunar operating space vehicles.

ASSOCIATE CONTRACTOR RELATIONSHIPS

In conformance with NASA directives issued during the NASA-MIT-S&ID meeting No. 15A, MIT/IL has supplied S&ID with the detailed reliability data necessary for the integration of guidance, navigation, and control equipment into the overall spacecraft. In Letter No. AG 726-64, dated 10 June 1964, MIT/IL reports as follows:

1. Responsibility - MIT has no basic disagreement except as noted below and feels the S&ID request is both proper and in line with a reasonable division of responsibility.

2. Definition of Backup Modes - MIT has contributed and will continue to contribute to S&ID data and other information defining backup modes, guidance and navigation system operational capabilities, and mission logic diagrams.

3. Component Data - MIT will assure that existing data adequately covers that requested by S&ID or will supply what is necessary.

4. Time-Significant Item List - The entire guidance and navigation system should be treated as a time-significant item with limitations and areas of criticality that have not been completely defined. Appropriate records should be maintained of guidance and navigation operating time in each mode, the number of cycles, the time in storage or environmental exposure, and any other exceptional condition. The S&ID process specification in preparation should reflect this requirement. MIT should be consulted on this specification before it is finalized and desires both to contribute to and to review the specification where guidance and navigation equipment is involved.

MIT/IL further agreed in this communication to review and comment upon reliability logic diagrams submitted to them by S&ID. Their comments, which include significant changes in the logic of the inertial measurement unit temperature controller, and various component or module failure rates, have been received, and necessary changes have been incorporated into the reliability logic diagrams for integrated guidance and control Block II configurations.

In keeping with this spirit of cooperation, S&ID is preparing for a technical meeting with MIT/IL on the subject of reliability. It is expected, further, that this program of direct technical liaison between S&ID and the associate contractors, which is necessary for the integration of Government-furnished and other electronics equipment into the spacecraft, will be accelerated and enlarged.

PLANNED ACTIVITIES

Plans for the next quarter include the acquisition of more detailed data on guidance, navigation, and control interfaces for Block II configurations; data on rendezvous radar functional interrelationships with spacecraft optical and guidance, navigation, and control equipment; S-IVB interface evaluations; and review of the results of the S&ID apportionments study.

INSTRUMENTATION

CENTRAL TIMING EQUIPMENT

Several supplier part specifications, previously conditionally approved, have been revised to reflect S&ID comments and have been evaluated and approved. One of the integrated circuits that had failed in the E2 model (see the Tenth Quarterly Reliability Status Report, SID 62-557-10) was submitted to the part supplier for analysis. Sectioning of the circuit revealed that a surface defect had allowed leakage between the N-type region of a transistor collector and the N-type region of a diode cathode. These two elements are separated only by a narrow strip of P-type substrate. The cause of the failure has not been determined, but the manufacturer is confident that burn-in will detect this type of failure. Present integrated circuits require a burn-in with very tight parametric limits; i.e., a catastrophic failure is not the only reject criterion.

The central timing equipment prototype sustained a failure during development vibration testing. During post-test checkout of the redundancy test points, it was found that one of the redundant power supplies was not operating. Analysis revealed that a connection at one of the power transistors had failed due to metal fatigue; inadequate structural support at this point was evident. The area had not been potted in order to reduce weight and because potting was originally felt to be unnecessary. An engineering change has been initiated to include potting as a result of this failure.

Upon failure of the power supply, the redundant power supply operated as designed, and all outputs of the central timing equipment continued to function.

A potential reliability problem area was alleviated through redesign of the oscillator to allow replacement of the potentiometer by fixed resistors.

The nonredundant time accumulator design is complete. A power saving of approximately 315 watts and significant weight and volume savings have been realized. Manufacturability and maintainability improvements will result from the package design analysis now in progress.

The failure reporting system, previously a weak area in the supplier's program, is being strengthened and is expected to be finalized near the end of this report period. The failure reporting and analysis procedures have been overhauled to place emphasis on timely reporting, rigorous analysis, and effective corrective action.

The reliability prediction and failure mode and effects analysis are being performed for the central timing equipment D models and should be complete early in the next report period.

TELEVISION CAMERA

Specifications for the wide-angle and zoom lenses have been submitted by the supplier to S&ID. Evaluation is complete; discrepancies have been noted for correction prior to final approval. Optical design for the zoom lens, except for the view finder, was completed; mechanical design is in progress. A partial redesign of the wide-angle lens was required because of mechanical unacceptability.

Failures were experienced in one of the integrated circuits of the cathode blanking and horizontal drive output. Collector-to-emitter break-downs occurred in transistors when the circuit was operated with a 5-volt power supply, although the circuit is rated at 12 volts. The failures prompted a decision to replace the circuit with a simplified hybrid circuit. The effective change was from a four-transistor, six-resistor circuit to a two-transistor, two-resistor, one-diode circuit. Tests on the new circuit have shown good results. The supplier has initiated a formal failure reporting and analysis system to include all levels of testing. The supplier will report to S&ID all failures occurring at the camera level of assembly. All failures at lower levels of assembly will be reported in house and will be available to S&ID for review.

The TV camera qualification test procedure was evaluated, and changes were proposed.

UP-DATA LINK

The supplier has submitted a reliability estimate report reflecting the frozen design of the Apollo up-data link. The estimate slightly exceeds the reliability goal specified in the up-data link procurement specification, MC 470-0014. Failure mode effect and circuit stress analyses have not been completed, but should be available for S&ID review soon. Approval was given on the supplier's parts recommended for exemption from identification and traceability requirements. The procurement specification was revised to include the latest design and test requirements regarding humidity and salt atmosphere.

CONTROLS AND DISPLAYS

The following plans and lists were reviewed during the report period:

1. Operating time/cycle lists for the caution and warning system and electrical meters

2. Nonstandard and electronic parts lists for the caution and warning system and the digital event timer

3. The supplier's identification and traceability revised plan for the hermetically sealed switches and potentiometers

4. The sampling plan for electrical meters

The following equipment test procedures were evaluated and changes were proposed:

1. Caution and warning system qualification test procedure

2. Rotary switch acceptance test procedures

3. Potentiometer acceptance, qualification, and development test procedures

4. Toggle switch acceptance test procedures

5. Rheostat acceptance, qualification, and development test procedures

6. Panel assembly data distribution qualification test procedures

7. Event indicator acceptance, qualification, and development test procedures

8. Altimeter acceptance test procedure

9. Push-button switch acceptance test procedures.

INSTRUMENTATION

The following equipment test procedures were evaluated and changes were proposed:

1. Pressure transducers - Three qualification test procedures

2. Temperature transducers - Four qualification test procedures

3. Temperature measurement system - Acceptance test and qualification test procedures

4. Mass flow sensor - Acceptance and qualification test procedures

5. Transducer and signal conditioner - Acceptance test procedure

6. Three-axis rate gyro accelerometer - Acceptance test procedure

7. Vibration measurement system - Acceptance and qualification test procedures

8. Linear accelerometer - Acceptance and qualification test procedures

9. Ablation sensor - Qualification test procedure

10. Sensor char layer - Qualification test procedure

11. Stress measurement system - Acceptance and qualification test procedures

12. Dual-channel signal conditioner - Acceptance test procedure

13. Transducer, thermal flux - Acceptance and qualification test procedures

14. Strain-gauge transducer - Qualification test procedure

15. Magnetic-tape recorder - Acceptance test procedure

16. pH monitor system - Acceptance test procedure

The development tests have been completed on the char-layer transducer, and a test report was received from the subcontractor. Fully qualified units will be delivered in January 1965.

During the past quarter, the qualification tests of the temperature measurement system, MC 431-0022, were completed by the subcontractor. Qualification was initiated on the pressure measurement system, MC 449-0005, and Phase C tests have been completed. It is anticipated that the remaining tests will be completed by the end of next quarter. The stress measurement system, MC 901-0114, started Phase C qualification, and combined temperature and vibration tests were successfully completed on the sensors. Problems were experienced with the signal conditioners during this environment testing because of the instability of components. The supplier and S&ID are presently reworking the specimens; corrective action (the replacement of components with those of higher stability) has been initiated, and retesting is planned. Delays caused by these failures were not significant.

It is anticipated that qualification will start on the following systems and components during the next quarter:

1. Ablation measurement system, MC 431-0024
2. Char measurement system, MC 431-0026
3. Resistance temperature sensor, MC 432-0082
4. Surface heat flux measurement system, MC 432-0088
5. Displacement transducer, MC 449-0014
6. Mass flow transducer, MC 449-0015
7. Linear accelerometer transducer, MC 449-0020
8. Temperature transducer, MC 449-0021
9. Flow transducer, MC 449-0065
10. Acoustic measurement system, MC 901-0080
11. Vibration measurement system, MC 901-0112
12. Stress measurement system, MC 901-0114

STABILIZATION AND CONTROL

SUMMARY

The Block I procurement specifications and statements of work were reviewed and updated. Inputs to the Block II SCS specification and statement of work were completed. Technical problems in the areas of component reliability were reviewed, and action was taken to ensure compliance with requirements and schedules.

ANALYSIS

Integrated Guidance and Control Digital System

The reliability of the all-digital design concept for a guidance and control subsystem, which is being considered as a possible replacement for the present analog approach, was reviewed and evaluated.

The evaluation indicated this concept could not meet the mission success reliability requirement of 0.984 for the spacecraft electronics unless a minor redesign to allow real-time transfer from the primary computer (AGC) to the standby computer was made. This redesign would allow the second computer to be off until a failure occurred in the primary computer. The present concept calls for both computers to be on in a standby condition even when no function is being performed which exhibits potential failure that would preclude attainment of mission success reliability.

Reevaluation of the Body-Mounted Attitude Gyro (BMAG) Reliability

The BMAG reliability was reevaluated. Utilizing all available information, such as past experience on similar gyros, parts count, component (spin motor, etc.) failure and test data, and design proof test results, new failure rates were derived for the BMAG's. The failure rate of the gyro is affected by certain specific conditions, such as prelaunch trim of non-g sensitive parameters, pampering (special handling and temperature control), and tolerance requirements.

Table 11 gives a matrix of the gyro failure rate associated with each of these conditions. The 1400-hour figures indicated in this table are for both ground and flight environments, while the 400-hour figures are only for flight environments. A higher failure rate is associated with the 1400-hour figures because ground handling and ground environments are considered more detrimental than the flight period to the proper operation of the gyros.

Table 11. Body-Mounted Attitude Gyro Failure Rates

Attitude Gyro	Failure Rates (percent per 1000 hours)					
	Prelaunch Trim (5 days to flight)		No Prelaunch Trim		1. No Prelaunch Trim *2. Reduction in Non-G Sensitive Tolerance	
	Pampered	Nonpampered	Pampered	Nonpampered	Pampered	Nonpampered
Ground and Flight Environments Included (1400 hours)	6.2	7.0	15.0	20.0	6.2	7.0
Flight Environments Only (400 hours)	4.0	4.5	14.0	15.0	4.0	4.5

*Reduced from one degree per hour to two degrees per hour non-g sensitive drift rate

The possibility of lowering the non-g sensitive drift rate or allowing prelaunch trim are under investigation. For reliability purposes, the prelaunch trim requirement must be deleted to achieve an acceptable failure rate. This would delete the requirement for trim pots in the gyros as stated in the Ninth Quarterly Reliability Status Report, SID 62-557-9.

NASA Proposed Block II Integrated Guidance and Control

Reliability logic diagrams for both mission success and crew safety have been generated for the NASA-proposed Block II integrated guidance and control subsystem. Based upon the proposed configuration, failure rates have been developed to be utilized with the logic in the development. At the completion of the spacecraft apportionment, the procurement specification will impose failure rate requirements upon the SCS subcontractor.

SUBCONTRACTOR MANAGEMENT

Block I Stabilization and Control Procurement Specification

Due to the deletion of the in-flight maintenance concept, the procurement specification for the Block I stabilization and control subsystem has been revised to delete the reliability objectives of 0.995 for mission success and 0.999 for safe abort. These numerics, which are a function of time, are being replaced with failure rate requirements consistent with the Block I philosophy and missions.

Spacecraft 009 Control Programmer Procurement Specification

The control programmer specification was reviewed and updated to incorporate in the Block I subsystem the latest qualification test philosophy, that there will be no duplication of environmental testing. As part of this review, a meeting was held with Lockheed Missile and Space Division to determine what steps must be taken to allow the purchase of Lockheed off-the-shelf sequential timers for use in the control programmer. The results of the meeting have been submitted to NASA for concurrence.

Block II Stabilization and Control Procurement Specification

The reliability inputs to the Block II SCS procurement specification have been submitted. In line with the cost reduction program, the procurement specification reliability requirements were modified to include failure rates at the applicable level to the redundancy and subsystem interaction, rather than give reliability requirements at the subsystem level. The failure rate requirements will be incorporated as a result of the spacecraft reapportionment now being performed. The procurement specification also includes the latest environmental design criteria and test requirements. A specific change being incorporated in the specification is that MIL-STD-810 is replacing MIL-E-5272 as the testing guide.

Block II Stabilization and Control Statement of Work

The reliability input for the Block II SCS statement of work has been submitted. This statement describes all the tasks, requirements, and documentation the subcontractor must perform or meet to satisfy the reliability requirements of the procurement specification. Peculiar to this input was the explicit delineation of tasks required by the subcontractor in the preparation of his reliability program plan.

III. MECHANICAL SUBSYSTEM ANALYSIS

COMMAND MODULE HEAT SHIELD

ANALYSIS

Failure Effects Analysis

Failure effects analyses reflecting design changes inherent in Spacecrafts 006 and 009 through revision P were completed. The failure analysis for Spacecraft 009 is included in the AVCO monthly progress report, RAD-SR-64-194, dated 10 July 1964.

Ablator Thickness Control

A plan for checking the thickness of the heat shield has been completed. This plan will provide assurance that all portions of the ablator are within the required thickness limits. It requires measurement of thickness at a minimum of 162 points about the heat shield. The technique used provides for the estimation of the constants in an error-generating mathematical model. This model predicts the thickness error as a function of the location on the heat shield. The rejection criteria will be the limits imposed on allowable error for each measurement. Details of this plan are found in the AVCO monthly progress report, RAD-SR-64-210, dated 11 August 1964.

TEST PROGRAM

The following development test activity took place at AVCO Corp. during this reporting period. Details of these tests are in AVCO monthly progress reports RAD-SR-64-155, RAD-SR-64-194, and RAD-SR-64-210 for June, July, and August, respectively.

1. Ablation tests
2. Failure criteria beam tests
3. Failure criteria compression tests
4. Failure criteria tensile tests
5. Shear compression pad mockup load tests

6. Vibration beam tests

7. Bond peel tests

8. Cold soak tests

9. Humidity exposure tests

10. Station 81 gap finger seal test

11. Radiant heated gap seal test

12. Window frame bond screening test

Development tests are approximately 94 percent complete at the present time.

The Qualification tests scheduled for September 1964 are being rescheduled because of program reorientation.

COMMAND MODULE REACTION CONTROL

SUMMARY

Recommendations have been made to establish statistical measures for CM RCS engine acceptance. The data spread is now related to the average specific impulse over several independent test points to yield a 10-percent maximum risk of accepting an engine with below-specification performance. These terms are sufficient to establish similarity between the engine in test and the engines which will have successfully passed the qualification tests.

Considerable coordination between design groups has resulted in a collection of current design information to be used during a scheduled design review.

A more detailed review of subsystem reliability as dependent on squib valves has been presented. The data presented in the Tenth Quarterly Reliability Progress Report, SID 62-557-10, has been amplified to include logic diagrams. The result clearly indicates the dependence on the helium pressurization squib valves.

ANALYSIS

Boilerplate 14 Reliability Analysis Support

A reliability analysis was completed evaluating the ability of Boilerplate 14 to simulate the Spacecraft 009 mission. The unfinished design of the unique, partially functional CM RCS as it is planned in Boilerplate 14 was utilized, and CM RCS criteria (description, functions, requirements, and constraints) were redefined accordingly. A CM RCS single-point failure mode and effects analysis (FMEA) was completed within the restrictions of this study. A logic diagram illustrating the relative effect of these restrictions was reviewed and corrected. These results will be presented with the data package for Boilerplate 14.

Block II CM RCS Design Changes

A reliability analysis of the proposed CM RCS Block II design change was evaluated. One proposed change, to obtain a more favorable center of gravity, was the relocation of a helium pressure vessel and associated tubing.

[redacted] [redacted]

Several undesirable effects which would result from this change were noted, including the addition of extensive high-pressure tubing and the potential loss of pressure supply redundancy. From the resulting proximity of the pressure vessels, a sympathetic rupture of the redundant tank most likely would occur in the event of a rupture failure of its neighbor. These objections were transmitted to Design, but the proposal was not adopted.

Another proposed change was the relocation of CM RCS equipment support panels. This change was determined to have no detrimental effect on reliability and has been implemented.

Squib Valve Reliability Analysis Revision

A CM RCS squib valve configuration reliability study reported in the Ninth Quarterly Reliability Status Report, SID 62-557-9, was reviewed. For that study, the reliability values shown in Table 12 were utilized, as well as the logic diagrams of squib valve functions in Figure 13. The helium pressurization squib valves in the logic diagrams are in series logic because of the requirement that the command module not impact with a pressurized helium tank (4500 psi) which would result in an unacceptable crew hazard. Mathematical simulation of these logic diagrams resulted in the following equations.

Normal reentry (4)

$$\text{Success} = R_v^2 \Big(R_v^6 R_{eb}^2 + 6R_{eb}^2 R_v^5 Q_v + 2R_v^6 R_{eb} Q_{eb} + 8R_v^5 Q_v R_{eb} Q_{eb} + 9R_v^4 Q_v^2 R_{eb}^2 + 8R_v^4 Q_v^2 R_{eb} Q_{eb}\Big)$$

Abort (low altitude) (5)

$$\text{Success} = R_v^2 \Big(R_v^5 + 5R_v^4 Q_v\Big)\Big(R_{eb}^2 R_v^3 + 3R_{eb}^2 R_v^2 Q_v + 2R_{eb}\, 8_{eb}\, R_v^3\Big)$$

where

Engine bank reliability, $R_{eb} = 0.99956$

Engine bank probability of failure, $Q_{eb} = 1 - R_{eb} = 0.00044$

Valve and initiator reliability, R_v = Configuration of Table 12.

[redacted] [redacted]

The equations are related as follows:

$$\begin{pmatrix}\text{S-1 Booster} \\ \text{Success (0.95)}\end{pmatrix} \begin{pmatrix}\text{Normal Reentry} \\ \text{Success}\end{pmatrix} + \begin{pmatrix}\text{Booster} \\ \text{Failure 0.05}\end{pmatrix}$$

$$\begin{pmatrix}\text{Abort} \\ \text{Success}\end{pmatrix} = \begin{pmatrix}\text{Squib Valve} \\ \text{Mission} \\ \text{Reliability}\end{pmatrix}$$

Calculations resulted in the numeric values in Table 13.

Table 12. Elemental Reliability Values

Element	Reliability	Source
Valve (mechanical portion)	0.9999	Procurement specification
Initiator		
Single energized bridgewire	0.999	Procurement specification
Two energized bridgewires	0.99995	Estimate based on evaluation of all series failures
Configuration		
1. Single valve, single initiator, single energized bridgewire	0.9989	
2. Single valve, single initiator, two energized bridgewires	0.99985	
3. Single valve, two initiators, single energized bridgewire each	0.99990	
4. Two valves, single initiator each, single energized bridgewire each	0.999998	

[redacted] [redacted]

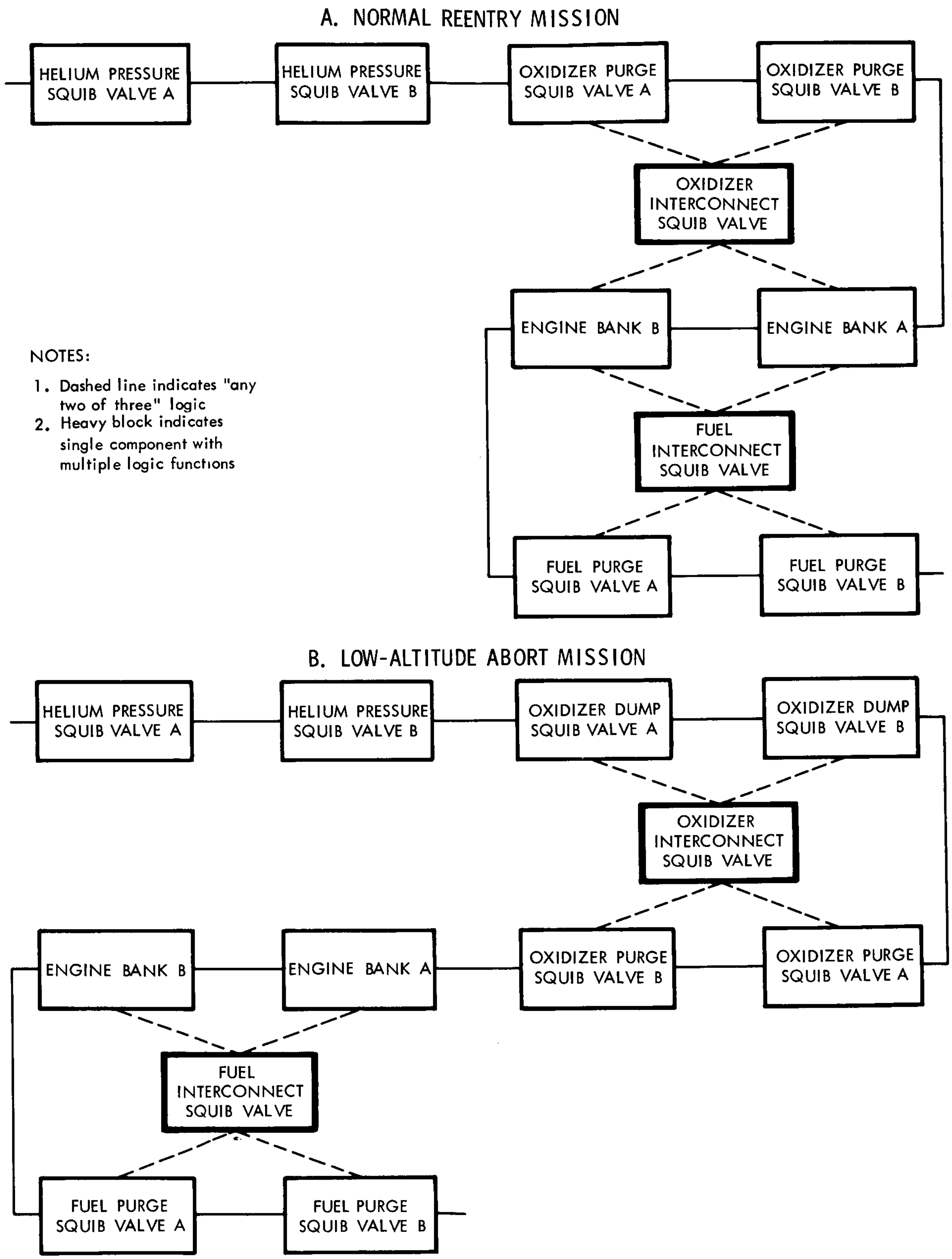

Figure 13. Squib Valve Logic Diagrams

 [redacted]

Table 13. Squib Valve Wiring Reliability Study

System Squib Valve Configuration No.	Description	Helium Pressure Valve Elemental Configuration	Failures/10^6 Missions
1	Twelve valves with current configuration (one electrical source to one bridgewire)	1	2200
2	Twelve valves with two electrical sources to two bridgewires in a single initiator	2	300
3	Twelve valves with two electrical sources to two separate initiators per valve	3	200
4	Twelve valve positions with two electrical sources to redundant valves (total of 24 valves)	4	4
5	Ten valves with two electrical sources to two bridgewires (but one initiator), plus two helium valves with two initiators and separate sources	3	200
6	Ten valves with two electrical sources to two bridgewires (but one initiator) plus two helium valve positions with redundant valves and separate sources	4	4
7	Six valves with current configuration one electrical source to one bridgewire, plus four interconnect valves with two sources to two bridgewires (but one initiator), plus two helium valves with two initiators and separate electrical sources	3	205

Table 13. Squib Valve Wiring Reliability Study (Cont)

System Squib Valve Configuration No.	Description	Helium Pressure Valve Elemental Configuration	Failures/10^6 Missions
8	Six valves with current configuration (one electrical source to one bridgewire), plus four interconnect valves with two sources to two bridgewires (but one initiator), plus two helium valve positions with redundant valves and separate sources	4	9
	Total system requirement		40

As a result of this study, some minimal design improvements were incorporated into the CM RCS; e.g., the unused bridgewire in the initiators of six valves were wired to a redundant electrical source. Therefore, the present design of the CM RCS utilizes squib valve Configuration 2 (i.e., a single valve with a single initiator which has two energized bridgewires) in six locations—the two helium pressurization squib valves and the four interconnect squib valves. The remaining six locations in the system—four purge squib valves and two oxidizer dump squib valves—utilize Configuration 1 (i.e., a single valve with a single initiator which has a single energized bridgewire).

Current revisions to the study data are as follows:

Revision One—As a result of failure mode analyses, the estimated reliability of the initiator with two energized bridgewires is changed from 0.99995 to 0.9999, which changes the reliability of Configuration 2 (valve with this initiator) from 0.99985 to 0.9998. This reduction was based on additional consideration of possible failure modes detected during the failure mode analyses, primarily in the charge strength which was experienced during current tests.

Revision Two—Change of the oxidizer dump squib valve from the "two of three" logic to series logic. This was necessary after an analysis of dumping times indicated that the interconnect feature of the design would not permit dumping of the oxidizer prior to parachute exposure. Thus, both oxidizer dump squib valves must operate during pad or low-altitude aborts to prevent an unacceptable crew hazard.

[redacted] [redacted]

The effect of these revisions and the recent design improvements on system reliability is being evaluated.

CM RCS Design Review

Final interdepartment coordination effort to support an Engineering Review Board (ERB) presentation was completed. Analyses were completed which will be used for a Reliability Design Review scheduled in October 1964.

SUBCONTRACTOR MANAGEMENT

Acceptance criteria for specific impulse of the command module reaction control engine were developed to compensate for error of observation due to inherent system instrumentation inaccuracy and to reduce to 10 percent the probability of accepting engines with less than 266 seconds of specific impulse (Figure 14). The system devised allows acceptance based on as few as two sets, depending on the average specific impulse value of the tests and the range of the data points. These acceptance criteria were accepted by the subcontractor and incorporated in the C revision of the subcontractor process specification, RA 0220-325, titled SE 8-4 and SE 8-5 Rocket Engine Assembly Data Reduction for Steady-State Operation.

Acceptance criteria also have been developed for pulse mode specific impulse of the CM RCS engine to reduce to 10 percent the probability of accepting an engine with less than the required specific impulse—as shown in Figure 15. These criteria consist of a family of curves showing the maximum allowable data point spread about the average specific average values. The criteria apply to a minimum sample of 15 pulses. In application, the best-fit curve of data points from hot fired pulses shall be at least one second above the specification curve, with a maximum range of ten seconds for all pulse widths. For higher best-fit curves, the range can be increased.

These criteria, after coordination with Engineering, will be included in Amendment 4 of Procurement Specification MC 901-0067B.

TEST PROGRAM

CM RCS Engine

Development of a noncracking throat insert capable of any mission duty cycle without performance degradation continues to be a primary effort. Three flightweight engines have been tested with a JTA throat cushioned by TR-69, a flexible ablative material. All engines have completed calibration firing tests with no indication of throat cracking. Materials are still being

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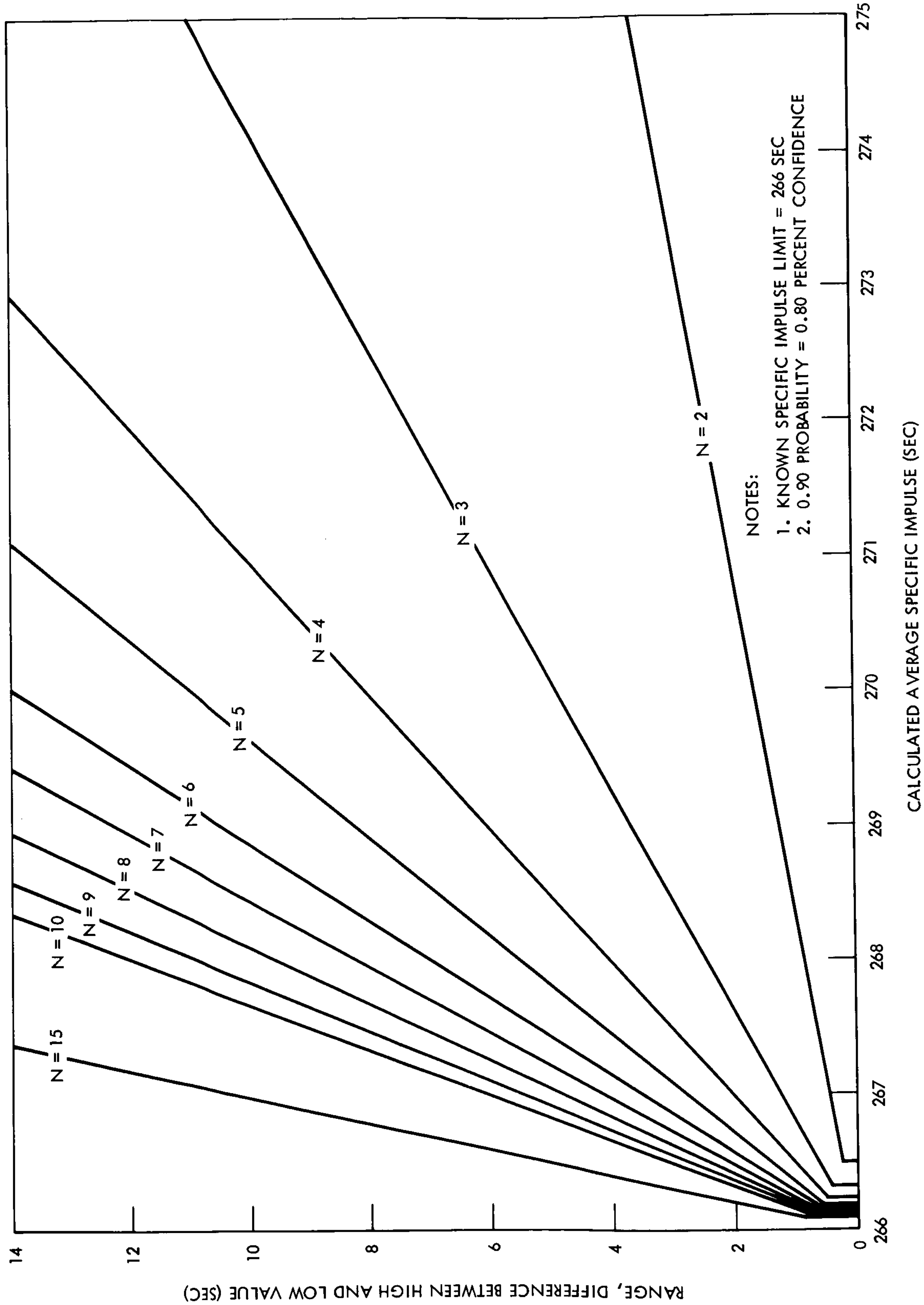

Figure 14. Acceptance Limits for Specific Impulse of RCS

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[redacted]

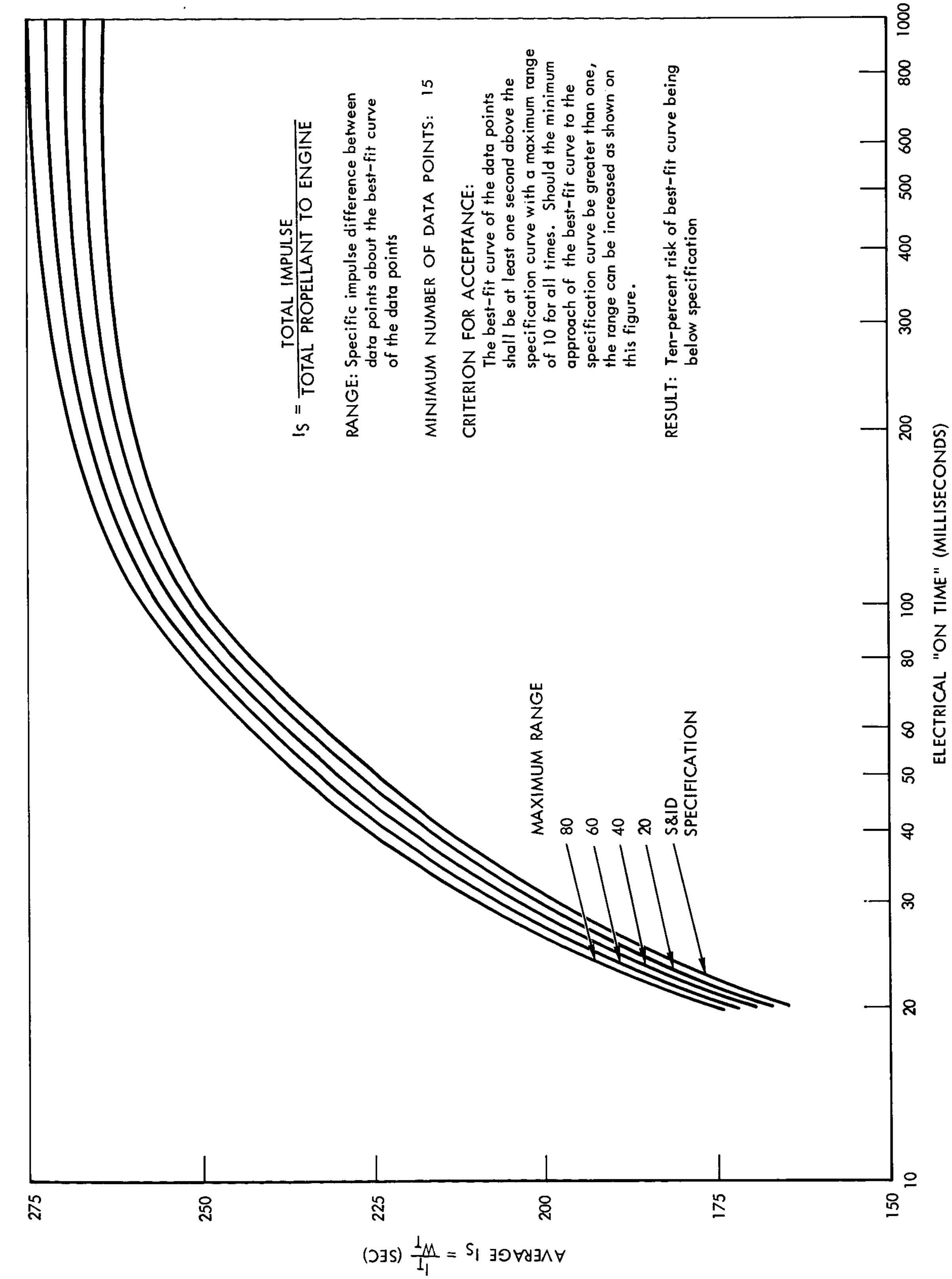


Figure 15. Transient Specific Impulse

[redacted]

tested to replace the JTA liner and zero-degree backing material. To date, the 45-degree precharred ablative material appears to be most favorable.

Rocketdyne has been directed to reduce the number of Apollo engines to be fabricated for the qualification test program from 16 to 8. The revised schedule for the qualification test program is from 20 November 1964 to 1 April 1965.

Two sets of lightweight valves have been through the high-temperature and vacuum tests of the component test phase. The life cycle tests have been completed on one set of valves. Tests are being conducted to solve the humidity sealing problem on the header assembly.

CM RCS Propellant Feed

The following three component suppliers have completed the qualification phase of testing and are preparing to initiate off-limits testing phases:

1. Lear-Siegler-Romec, test point coupling disconnects
2. Resistoflex, dynatube special end fittings
3. J. C. Carter, propellant coupling disconnects

The following seven component suppliers have completed the design verification phase of testing and are preparing to initiate or have started qualification testing:

1. On Mark, helium fill coupling disconnect
2. Fairchild-Stratos, helium pressure regulator valve
3. Calmec, pressure relief valve
4. Apco, helium check valve
5. Pelmec, helium isolation valve, explosive operated
6. Menasco, helium pressure vessel
7. Titeflex, flexible metal hose

Development efforts are being accomplished by three suppliers:

1. Bell Aerosystems, propellant tank assemblies

[redacted]

2. Eckel, propellant solenoid valves

3. Sargent-Fletcher, helium solenoid valve

Bell Aerosystems is experiencing difficulty in achieving a suitable bladder configuration. Expulsion efficiencies have been improved, but expulsion cyclic requirements continue to be a major problem. Because of continuing problems with ply separation upon exposure to propellants, efforts are being concentrated on evaluation of 6-mil, single-ply bladder configurations. Development tests are being made with 6-mil, single-ply, net-size bladders.

Eckel Valve Company is continuing development efforts on the propellant valve configuration redesign. Material-propellant compatibility and positive positioning are the primary areas of concern.

Sargent-Fletcher is conducting development and design verification efforts concurrently. Development efforts are directed to the investigation of a propellant vapor compatibility configuration. Design verification testing is being conducted on a valve configuration that has not been required to meet propellant vapor compatibility.

COMMAND MODULE STRUCTURE

SUMMARY

The astro-sextant door components (actuator and screw jack) are scheduled to start qualification in September 1964. Exploratory tests were successfully completed on the crew hatch latching mechanism this quarter. Because the hardcoated housings failed preliminary inspection, all manufacturing of the oxygen control system has been stopped, and further development testing is being performed. Development testing of the crew couch shock strut assembly was delayed so the test program could be redefined to best utilize the scheduled tests for the LOR strut configuration hardware.

The mechanical devices test status of system and major components is presented in Table 14.

TEST PROGRAM

Astro-Sextant Door

Partially qualified hardware is scheduled for delivery and system tests are scheduled to start in November 1964.

Crew Hatch Latching Mechanism

The tests completed this quarter successfully demonstrated that the hatch latching mechanism design is acceptable, thereby, finalizing the basic design configuration. Component qualification will be limited to the latch actuator. System qualification tests shall be performed by S&ID. The detailed system test procedures are scheduled to be released in December 1964.

Oxygen Control System

Qualification tests have been rescheduled to start in November 1964 because the coating processes were being improperly controlled. Analysis of the problem indicated cracks and chips in the hardcoat and improper density and hardness of the coating material. Evaluation tests of the new coating processes are underway and are scheduled to be complete in the next quarter. Formal corrective action is pending the results of these tests.

[redacted] [redacted]

Table 14. Mechanical Devices Test Status

Item	Completion Dates	
	Development Tests	Qualification Tests
Astro-sextant door		
Complete Mechanism (system)	Not applicable	Apr 1965
Rotary flex shaft	1	2
Actuator	3	Oct 1964
Screw jack	3	Nov 1964
Crew hatch latching mechanism	Aug 1964	To be determined
Actuator	Jan 1965	Mar 1965
Oxygen control system	May 1964	Mar 1965
Crew couch strut assembly	Jan 1965	To be determined
CORE, impact attenuation	3	Mar 1965
Strut lockout mechanism	Jan 1965	2
Crew couch assembly	Aug 1965	Dec 1965
Canard system	Nov 1964	Jan 1965

[1] Off-the-shelf hardware, no formal development tests performed by the supplier

[2] To be qualified during system tests

[3] Modified off-the-shelf hardware, partially qualified at the supplier; no formal development test program

Crew Couch Strut Assembly

Formal design verification of the LOR couch strut assembly is scheduled to start in October 1964.

[redacted]

Crew Couch Assembly

Environmental and structural tests on the basic crew couch assembly are to be combined with other tests already planned so that all tests and test facilities will be fully utilized. The LOR couch configuration test hardware is scheduled for delivery in August 1965.

CREW PROVISIONS

ANALYSIS

The status of crew provision reliability activities at the close of the quarter is presented in the following two lists, which also include the qualification testing criticality rankings. These rankings are defined as follows:

I. Those components or functional elements considered "crew safety essential."

II. Those components or functional elements considered "mission success essential."

III. Components, functional elements, or subsystem failures having no effects on criticalities I or II.

This first list is comprised of those items and their respective qualification testing criticality rankings that are not considered essential for crew safety and will not be subjected to failure mode effect analysis. Since these items do not constitute a subsystem in themselves, a logic diagram analysis has not been generated for them. However, where applicable, these elements will be considered in the logic of the integrated systems at a later date.

Description	Criticality Ranking
1. <u>Crew Accessories</u>	
a. Light assembly (portable crewman)	III
b. Shelf assembly (work, food preparation)	III

Description	Criticality Ranking
2. Crew couch and restraint system	
a. Pad assembly (couch crewman)	III
b. Sandals (weightless restraint)	III
3. Window filter assembly	
a. Filter assembly (forward viewing window)	III
b. Filter assembly (side viewing window)	III
c. Filter assembly (hatch window)	III
4. Survival provisions	
a. Light assembly (locator CM)	III
b. Provisions assembly (crewman survival)	III
5. Personal hygiene equipment	
a. Cleansing pad set	III
b. Dentifrice set	III
c. Towel assembly	III
6. Crew provisions storage	
a. Medical compartment installation complete	III
b. Food compartment assembly	III
c. Hygiene compartment installation complete	III
d. Clothing compartment	III
e. Provisions assembly (crewman terminal survival collective)	III
f. Drawer assembly (food)	III

The second list is comprised of those items within crew provisions that will be subjected, where applicable, to failure mode effect and logic diagram analyses. The status of these analyses is mentioned.

Description	Criticality Ranking
1. Crew couch and restraint system	
a. Harness assembly (restraint crewman)	I
b. Restraint assembly (station crewman)	II
Status: The analysis of this area remains unchanged from that presented in the sixth quarter.	
2. Crew equipment	
a. Umbilical assembly (crewman)	I
Hose assembly umbilical Connector assembly (cabin oxygen umbilical hose) Seal (crewman umbilical)	
b. Hose assembly (oxygen)	I
Recharge (plss-ECS)	
c. Belt assembly (inflight crewman)	II
d. Delivery assembly (water personal)	II
Status: Updating of the analysis in this area is currently in progress. Completion is anticipated during the next reporting period.	
3. Waste management system	
Status: The analysis in this area will be updated to reflect the deletion of the bacteria control unit.	

TEST PROGRAM

Waste management system component design verification testing is 90-percent complete. Qualification testing of two waste management components were started this quarter. Table 15 indicates the test status of these components. Qualification test procedures for S&ID in-house fabricated crew systems hardware were initiated.

Table 15. Waste Management System Component Test Status

Component	Development (% complete)	DVT (% complete)	Qualification (% complete)
Backup valve	100	100	100
Waste management control unit	100	90	20 (to be rerun)
Ventilating check valve	100	100	10
Bacteria control unit		Canceled this quarter	
Urine disposal lock	100	100	Sept 1964 (start)
Vacuum cleaner	90	80	Dec 1964 (start)
Blower	100	100	10

Waste Management Control Unit

In conformance with the required corrective action resulting from a previous qualification test failure, the supplier of the waste management control unit is fabricating a redesigned unit. The nature of this failure and the resulting corrective action were reported in the previous quarterly report. The supplier also is preparing the revised test procedures to incorporate the necessary hardware and test sequencing modifications. The restart date of qualification is now estimated to be November 1964.

Ventilating Check Valve

The supplier of the ventilating check valve halted qualification tests because of an inadequate internal leakage test fixture. Although no failure was encountered during the test (leakage was within specification tolerance), a check of the test setup revealed that it was not in balance. Further investigation revealed that the setup would fail to maintain proper balance throughout the test and the redesign was necessary. After redesign of the test fixture, the new test procedure was approved by S&ID. The qualification test hardware subsequently completed a rerun of the acceptance tests, including the internal leakage test, successfully.

Bacteria Control Unit

The bacteria control unit was cancelled by NASA during this quarter. All work has been stopped on this component, and it will be omitted from future reports.

Urine Disposal Lock

The supplier of the urine disposal lock was directed to stop all work on this component pending the outcome of the investigation resulting from the cancellation of the bacteria control unit. Upon determining that the cancellation of the bacteria control unit did not affect the urine disposal lock design requirements, the "stop work" order was removed. The order resulted in a two-month delay in qualification tests.

Vacuum Cleaner

Qualification of the vacuum cleaner has been rescheduled to start in December 1964 due to a redesign of the inlet check valve. The valve is being redesigned for manual operation to ensure maximum usable inlet area when the unit is functioning. Additional development testing is required as a result of this design change.

Waste Management Blower

Design verification testing of the blower was successfully completed. Upon receiving approval of their development report, the supplier started qualification testing. The qualification test units are now in acceptance testing. It is estimated that qualification will be completed in January 1965.

In-House Fabricated Crew System Hardware

Release dates for the detailed test procedures, Apollo Test Requirements (ATR's), for in-house fabricated crew systems hardware have been established. Preliminary drafts of these ATR's are now in progress. A summary of the ATR due date, date of test, and test report due date is presented in Table 16.

Table 16. In-House Crew System Fabricated Hardware Test Status

Component	ATR Number	*ATR Due Date	*Test Date	*Report Date
Food compartment assembly	6109. 0	12/64		
Food and work table drawer assembly	6109. 1	10/64		
Work and food preparation shelf assembly	6109. 2	11/64		
Forward medical compartment box assembly	6127. 0	9/64		
Aft medical compartment box assembly	6127. 1	9/64		
Fecal canister assembly	6139. 0	11/64		
Relief tube receptacle assembly	6139. 0	12/64		
Survival provisions container assembly No. 1	6162. 1	10/64		
Survival provisions container assembly No. 2	6162. 2	11/64		
Survival provisions container assembly No. 3	6162. 3	11/64		
Cabin O_2 umbilical hose assembly	6179. 1			
Crewman couch pad assembly	6261. 0	9/64		

*Dates not shown are to be determined.

PLANNED ACTIVITIES

Revision and updating of system logic diagrams and failure effects analyses will be continued for the following functional elements:

1. Umbilical assembly

2. Hose assembly (oxygen recharge)

3. Belt assembly (in-flight crewman)

4. Delivery assembly (water personal)

Further studies of interface areas with Government-furnished equipment will be conducted, with an emphasis on the Gemini space suit assembly. The recent transmittal of the Block I Space Suit Design and Performance Specification, MSC-CSD-02A, will be instrumental in initiating these studies.

CRYOGENIC STORAGE

SUMMARY

During this reporting period, several reliability studies were performed on the tank systems and the subcontractor reliability program was monitored. A logic diagram for Spacecraft 009 was prepared for the flight readiness report.

ANALYSIS

Special Studies

Tank Configurations

Several reliability analyses performed for proposed four- and six-tank systems used mean failure rates from the AVCO handbook, Reliability Engineering Data Series Failure Rates, dated April 1962. The criteria used to evaluate the six-tank system were:

1. One tank each of H_2 and O_2 is used completely during the first part of the mission.
2. After these first tanks are depleted, the remaining two tanks each of H_2 and O_2 are used at an equal rate.
3. Abort will not be accomplished if the first tank of each system fails.
4. Abort will be accomplished only after a second tank of each system fails.
5. Each of the three tanks of each system has enough fluid to complete half of the mission requirements.
6. Tank burst failures are not considered in this analysis.

The criteria used to evaluate the four-tank systems were:

1. All gas quantities are used at an equal rate throughout the mission.
2. Abort willbe accomplished if any single tank system failure occurs.
3. Tank burst failures are not considered in this analysis.

The reliability values for the two proposed systems, as compared to the present system, are as follows:

Type	Mission Success		Crew Safety
	t = 147 hrs	t = 255 hrs	
Proposed 4-tank system	0.987716	0.979200	0.99994
Proposed 6-tank system	0.999942	0.999835	0.99999
Present 4-tank system (MC901-0005C)	0.99890	—	0.99999

Diode Study

A proposal was made to the design group to add a second blocking diode in parallel with the existing one in each of the four-tank circuits. The blocking diode is used to prevent the 65-volt GSE power from entering the 28-volt vehicle power circuits. As the circuit is now designed with a single diode, a failure in the open mode would stop power to the heaters and cause a launch delay or even a launch abort, and a failure during flight would halt heater operation both in the automatic and manual modes (see electrical schematic V14-945804). A second diode would eliminate this single-point failure. Acceptance of this proposed change by the design group is pending.

Spacecraft 009 Logic Diagram

A logic diagram for Spacecraft 009 was prepared for the reliability flight support report. This spacecraft will have only one-half the usual cryogenic storage system for fuel cell operation.

Qualification Test Program Reorientation

An effort was made to reduce expenditures during fiscal year 1965 in the cryogenics qualification test program. The reduction was based on component and system criticality for manned and unmanned flights by Block I and Block II vehicles. The criticality categories were defined as:

Criticality I	Crew safety essential
Criticality II	Mission success essential
Criticality III	Component or subsystem failure having no effect on crew safety or mission success

Cryogenic storage system components were assigned criticalities by vehicle; the Qualification Review Board then determined the minimum test-sample size for the various test groups of the qualification program supporting each vehicle.

TEST PROGRAM

A development program for engineering models was initiated in September 1964 and should conclude in December 1964. This program encompasses thermal and vibration testing on two hydrogen models and two oxygen models. The testing will be comparable to qualification test requirements and will be used to verify system design.

Final data on the pressure-vessel qualification program from Beech Aircraft on the second oxygen pressure vessel, PV-3, showed that burst pressure was 2234 psi. The first oxygen pressure vessel, PV-1, burst at 2233 psi. Both vessels burst in the upper hemisphere near the neck of the vessel and propagated longitudinally through the weld. For both vessels, all tears exhibited good shear failures and exceeded the design requirements.

Of the 18 Globe fan motors submitted for acceptance testing, 14 failed during cryogenic shock testing. The stator lamination cracks were due to large tolerance variations during machining of the interior of the stator assembly. The four suitable units will be used on the engineering thermal and vibration tank models. All other units will be returned to Globe for rework. Closer machining tolerance will be maintained on reworked and on subsequent units.

A titanium vessel, PV-8, completed all phases of the pressure vessel qualification program. The vessel was ruptured hydrostatically and burst at 771 psi at room temperature. All fractures exhibited good shear characteristics. This was the last of the four titanium vessels that successfully completed qualification testing. A titanium electrical disconnect is being pressure-cycled and creep-tested. Fifty cycles at 300 psi, 550 cycles at 260 psi, and 72 of the 330 hours of creep test at 300 psi have been completed with no deformation.

The inconel connector has been welded into its assembly fixture and will be tested during the next reporting period.

Qualification Redirection

As a result of the cost-reduction exercise, the qualification program has been changed as follows:

1. All Phase A-2 off-limits testing will be deferred to fiscal year 1966.

2. The vacuum, pressure recovery, and quantity balance test have been combined into one test and scheduled as part of the Phase B life test.

3. One complete oxygen and hydrogen subsystem, less one tank each, has been deleted.

4. One oxygen subsystem and one hydrogen subsystem will be subjected to the Phase A-1 design proof tests during fiscal year 1965.

Qualification Schedule

The oxygen subsystem Phase A-1 qualification program, started in July 1964, should be completed in December 1964. The hydrogen subsystem Phase A-1 qualification program, started in August 1964, should be completed in January 1965.

SUBCONTRACTOR ACTIVITIES

Beech Aircraft has performed a cost-reduction analysis on the cryogenic system. The most promising cost reduction area is qualification testing, where some tests will be eliminated and others will be combined with the acceptance tests.

The logic diagram referenced in the Eighth Quarterly Reliability Status Report, SID 62-557-8, is contained in Beech document BR 13804B, dated September 1963.

PLANNED ACTIVITIES

During the next reporting period, the single-point failure summary will be completed and problem areas for Spacecraft 009 will be summarized for inclusion in the Reliability flight support report.

The Beech reliability program plan tasks will be evaluated on the basis of the new S&ID-NASA reliability task definition. Subcontractor direction will be provided as applicable as a result of the program evaluation.

EARTH LANDING

SUMMARY

The logic for the earth landing subsystem has been updated to reflect the optimized Block I changes. A recent design change has caused concern because redundancy has been eliminated from the main parachute disconnect. A return to full-detonator redundancy in lieu of considerable development effort necessary to increase the reliability of several components is under consideration.

The limited sensitivity of the inertia switches has brought about a change in the method of initiating parachute separation after landing. Present inertia switches, which are set for high shock, will be used only at WSMR; time-delay switches will be used for all water landings. Reliability is evaluating this change.

ANALYSIS

Earth Landing System Logic

The logic diagram for the Block I earth landing system has been updated to reflect the effects of the canard influence and dual-reefed drogues. This revised logic is shown in Figure 16.

The former redundant pyrotechnic design was eliminated in order to prevent a single-point failure (premature parachute disconnect). The present design requires the successful operation of both sequencer channels and both disconnect detonators to ensure success. The reliability of this system is limited to that of the series detonators (approximately 0.998). Failure to disconnect the parachutes would stop the uprighting bag system (see Single-Point Flotation in this section) from righting the CM out of the Stable II position. As long as the CM remains in Stable II, the recovery antennas are under water and transmission is impossible. Preliminary analysis indicates that mission success is jeopardized by the present design; the redundant detonators in the main disconnects may need to be reinstated.

Inertia Switches

Since the apparent inertia-switch failure on Boilerplate 6 (see the Ninth and Tenth Quarterly Reliability Status Reports, SID 62-557-9 and -10), steps have been taken to incorporate a revised operating-load criteria.

The minimum acceleration required to activate the switches will not be lowered because the sensitivity would be affected by the friction of the mechanism. Since the switches are set too high (8 g) for most water-landing attitudes, the reliability of these units in questionable. A decision was reached to use inertia switches for WSMR-launched vehicles only. All vehicles that will impact on water will use time delays in place of the inertia switches for the man parachute disconnect signal. Reliability analysis, based on mission goals, will be performed on the completed design.

Drogue Lanyard Switch

During Drop Test 50-11 at El Centro, the emergency drogue parachute was unintentionally deployed due to a malfunction of the telemetry switch. Analysis revealed that the switch failed when subjected to the brake-parachute release shock. A new switch has been incorporated which can withstand higher shock loads.

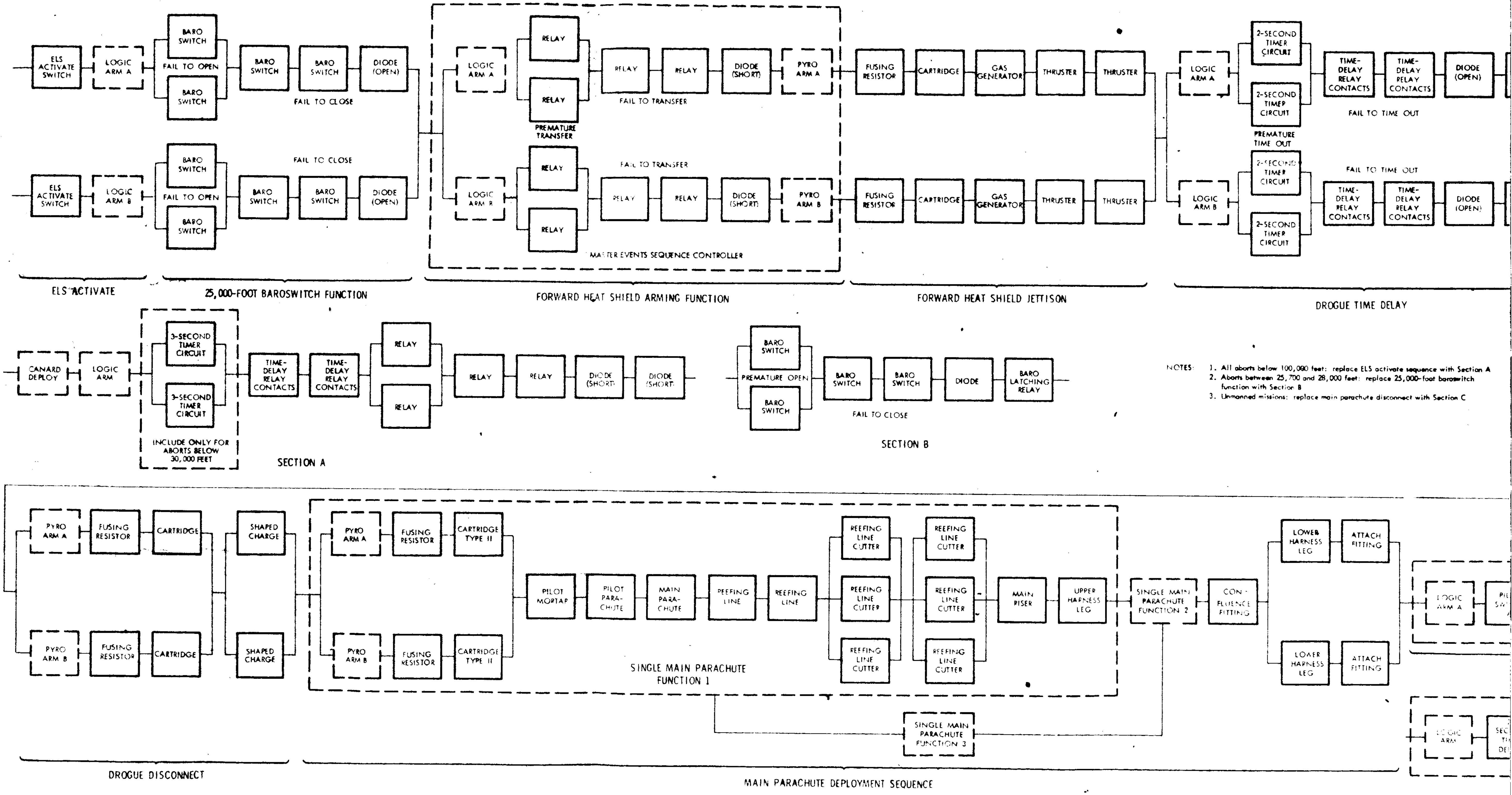
Single-Point Flotation

A reliability study was completed of several proposed systems to inflate the uprighting bags. The systems are designed to displace the CM from the Stable II position into Stable I and keep the CM in the upright Stable I attitude. Three systems were presented for consideration: an electric air pump, gas generators, and pressure bottles. The air-pump system has the highest reliability. Pressure bottles were rejected because of the danger of having a highly pressurized tank on board the CM at impact. On manned missions, circumstances could arise in which it would be desirable to deflate a bag and reinflate it later. Neither the pressure bottles nor the gas generators would have this capability unless lavish redundancy were used. The decision to use the single air pump was based on its inherent reliability, capability of reinflation, and low operation pressures. Failure of this pump to operate while the CM was in Stable II was not considered a single-point failure that would endanger crew safety, since an astronaut could open the hatch and erect a small recovery antenna. (All other recovery antennas are under water in the Stable II position.)

Since NASA direction forbids opening the hatch while the CM is in the Stable II position, the flotation system requirements are being reevaluated to determine if redundant motor pumps are necessary. Results of this study will be presented in a later report.

SUBCONTRACTOR MANAGEMENT

The subcontractor has chosen a new reefing-cutter supplier because of poor quality control and failure analyses experienced at the previous supplier.


ELS ACTIVATE SWITCH
LOGIC ARM A
LOGIC ARM B
BARO SWITCH
FAIL TO OPEN
FAIL TO CLOSE
DIODE (OPEN)
RELAY
PREMATURE TRANSFER
FAIL TO TRANSFER
DIODE (SHORT)
PYRO ARM A
PYRO ARM B
MASTER EVENTS SEQUENCE CONTROLLER
FUSING RESISTOR
CARTRIDGE
GAS GENERATOR
THRUSTER
2-SECOND TIMER CIRCUIT
PREMATURE TIME OUT
TIME-DELAY RELAY CONTACTS
FAIL TO TIME OUT
ELS ACTIVATE
25,000-FOOT BAROSWITCH FUNCTION
FORWARD HEAT SHIELD ARMING FUNCTION
FORWARD HEAT SHIELD JETTISON
DROGUE TIME DELAY
CANARD DEPLOY
LOGIC ARM
3-SECOND TIMER CIRCUIT
INCLUDE ONLY FOR ABORTS BELOW 30,000 FEET
SECTION A
PREMATURE OPEN
DIODE
BARO LATCHING RELAY
SECTION B
NOTES:
1. All aborts below 100,000 feet: replace ELS activate sequence with Section A
2. Aborts between 25,700 and 28,000 feet: replace 25,000-foot baroswitch function with Section B
3. Unmanned missions: replace main parachute disconnect with Section C
SHAPED CHARGE
CARTRIDGE TYPE II
PILOT MORTAR
PILOT PARA-CHUTE
MAIN PARA-CHUTE
REEFING LINE
REEFING LINE CUTTER
MAIN RISER
UPPER HARNESS LEG
SINGLE MAIN PARACHUTE FUNCTION 1
SINGLE MAIN PARACHUTE FUNCTION 2
SINGLE MAIN PARACHUTE FUNCTION 3
CON-FLUENCE FITTING
LOWER HARNESS LEG
ATTACH FITTING
DROGUE DISCONNECT
MAIN PARACHUTE DEPLOYMENT SEQUENCE

FOLD-OUT #1

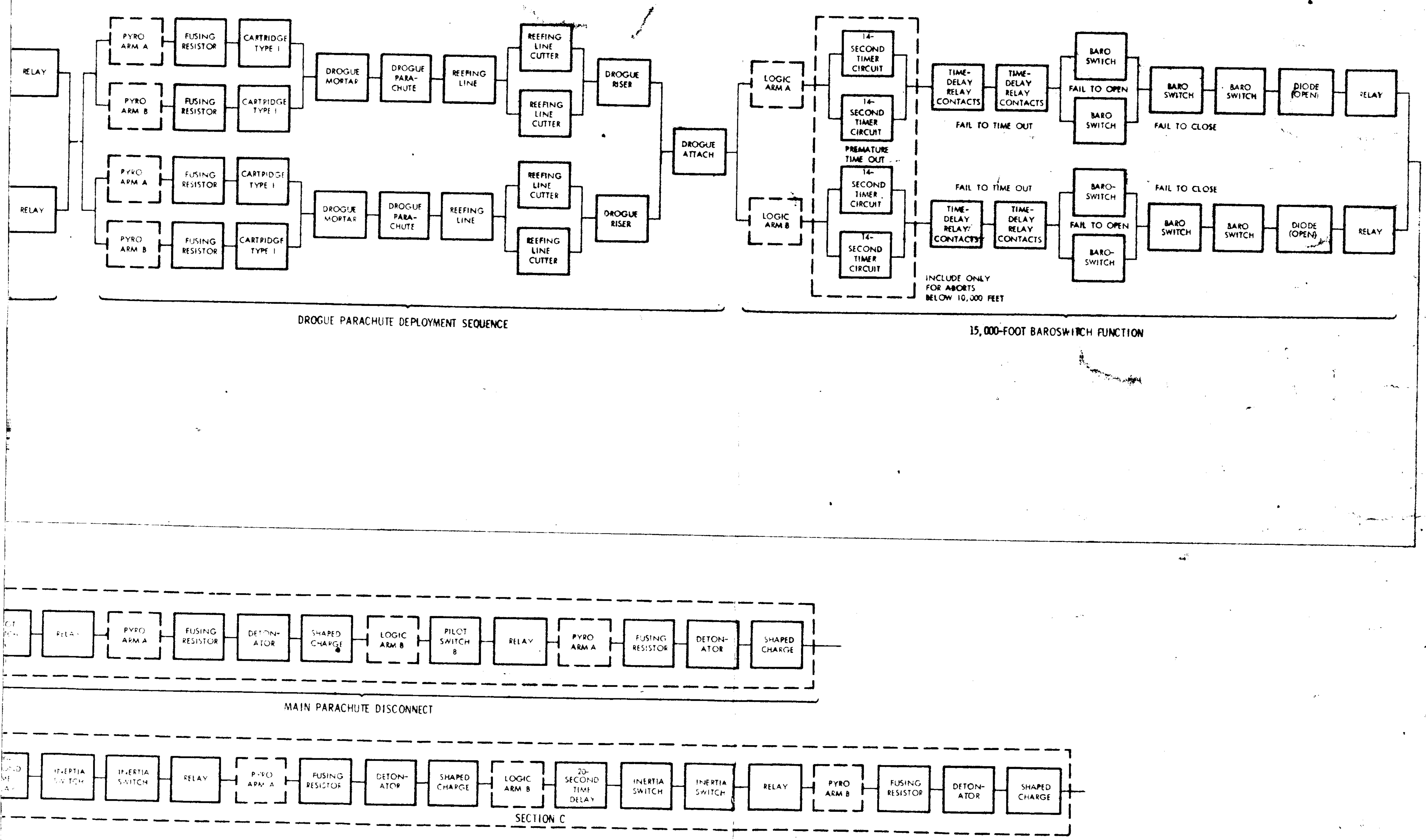


Figure 16. ELS Logic Diagram

FOLD-OUT #2

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Recent tests have revealed several problem areas in the new cutters. Excessive variation in required pull force is attributed to a solder seal that must be mechanically broken in order to extract the arming pin. The thickness of the solder cannot be controlled under existing manufacturing conditions. The supplier will experiment with welding techniques in an attempt to obtain a solution.

Excessive variations in time-delay train-burning time and self-extinguishment of the time-delay train before the main firing charge is reached are attributed to several causes:

1. The cutter-tube crimping unit was not aligned properly during assembly of an initial lot of cutters. This resulted in a displacement of the initiator mix from the main time-delay body. When actuated, the initiator mix burned out before jumping the gap and igniting the main time-delay train. This manufacturing defect has been corrected.

2. The supplier has attempted to manufacture 8-second time-delay cutters by using a slower burning mix in the original 6-second-length cutter tube. Because of space restrictions, the normal amount of initiator mix could not be inserted. As a result, the main time-delay train was not sufficiently ignited and would snuff out before reaching the cutter-propelling charge. The supplier has rectified this by decreasing the length of certain components slightly to allow sufficient room for the full charge of igniter mix.

Six cutters incorporating the above changes have been recently tested. All units fired successfully; however, some had a slightly longer delay time. This is not believed to be a serious problem.

TEST PROGRAM

Baroswitch

The search for an alternate source for baroswitches is continuing. The Gorn and Webb switches have been eliminated because of failures during vibration testing. Testing of the R&L Development Co. units has been delayed so that the switches can be modified to overcome a contact chatter encountered during vibration testing. The Servonic units are being tested.

A Radiflo test has been added to the subtier supplier acceptance tests of baroswitches. This is a result of corrective action taken after baroswitch leakage was uncovered during testing of the sequence controller.

Fabric Tests

The facilities of NAA/LAD are being used by Northrop-Ventura for vacuum-temperature tensile tests of parachute fabrics. The tests began in July and are scheduled to be completed by the end of October 1964. Tests to date have revealed no problems.

Qualification Tests

Qualification tests are scheduled to begin in January 1965 and be completed by August 1965. Off-limit and fabric tests were eliminated from the qualification tests program because of the Block I cost-reduction program. The fabric tests are being conducted as part of the development test program.

Flight Tests

The following drop tests were conducted at El Centro during this reporting period. All test objectives were satisfied.

Table 17. Earth Landing Subsystem Drop Tests

Drop Test Number	Date	Purpose of Test
63	6-10-63	Evaluate effect of (1) removal of top 75-percent of 5th ring, (2) removal of four gores from the standard 72-gore PDS 1543 main parachute, and (3) 9-percent midgore reefing for a two-parachute cluster.
64	6-18-64	Evaluate effort of nonsynchronous deployment and disreef for a two-parachute cluster.
65	7-1-64	Obtain performance data on two drogue parachutes with 6-second, 40-percent active reefing and 57-percent permanent reefing.
66	7-20-64	Obtain performance data on two drogue parachutes with 6-second, 40-percent active reefing and 57-percent permanent reefing.

Table 17. Earth Landing Subsystem Drop Tests (Cont)

Drop Test Number	Date	Purpose of Test
67	8-4-64	Evaluate effect of 75-percent open ring and 68-gore conical configuration with 9-percent midgore reefing on a 3-parachute cluster.
68	8-27-64	Obtain performance data on two drogue parachutes with 8-second 41-percent active midgore reefing and 64-percent permanent midgore reefing.

PLANNED ACTIVITIES

Corrective action taken on reefing time cutters will be followed up, main parachute disconnect redundancy will be reinstated, and the Boilerplate 23 minimum-airworthiness report will be prepared.

ELECTRICAL POWER

ANALYSIS

Fuel Cell Analysis

The logic diagram for the electrical power subsystem, during Phase A of the Apollo mission, (Figures 3, 4, and 5 in SID 62-557-8) has been changed to reflect revised abort criteria.

The new abort criteria for the fuel cell power plant subsystem are based on a two-phase mission. The first phase of the mission covers the period from launch to lunar landing; the second phase covers the period from the start of lunar stay through to service module separation.

Logic Diagrams

The logic diagrams presented in Figures 17 and 18 illustrate the revised criteria and should be used as a guide in updating the original logic diagrams. Mission success criteria are based on a minimum of two fuel cells operating during the translunar period (Phase I) and a minimum of a single fuel cell operating during transearth period (Phase II). Crew safety criteria are based on a minimum of one fuel cell operating during all mission phases up to service module separation.

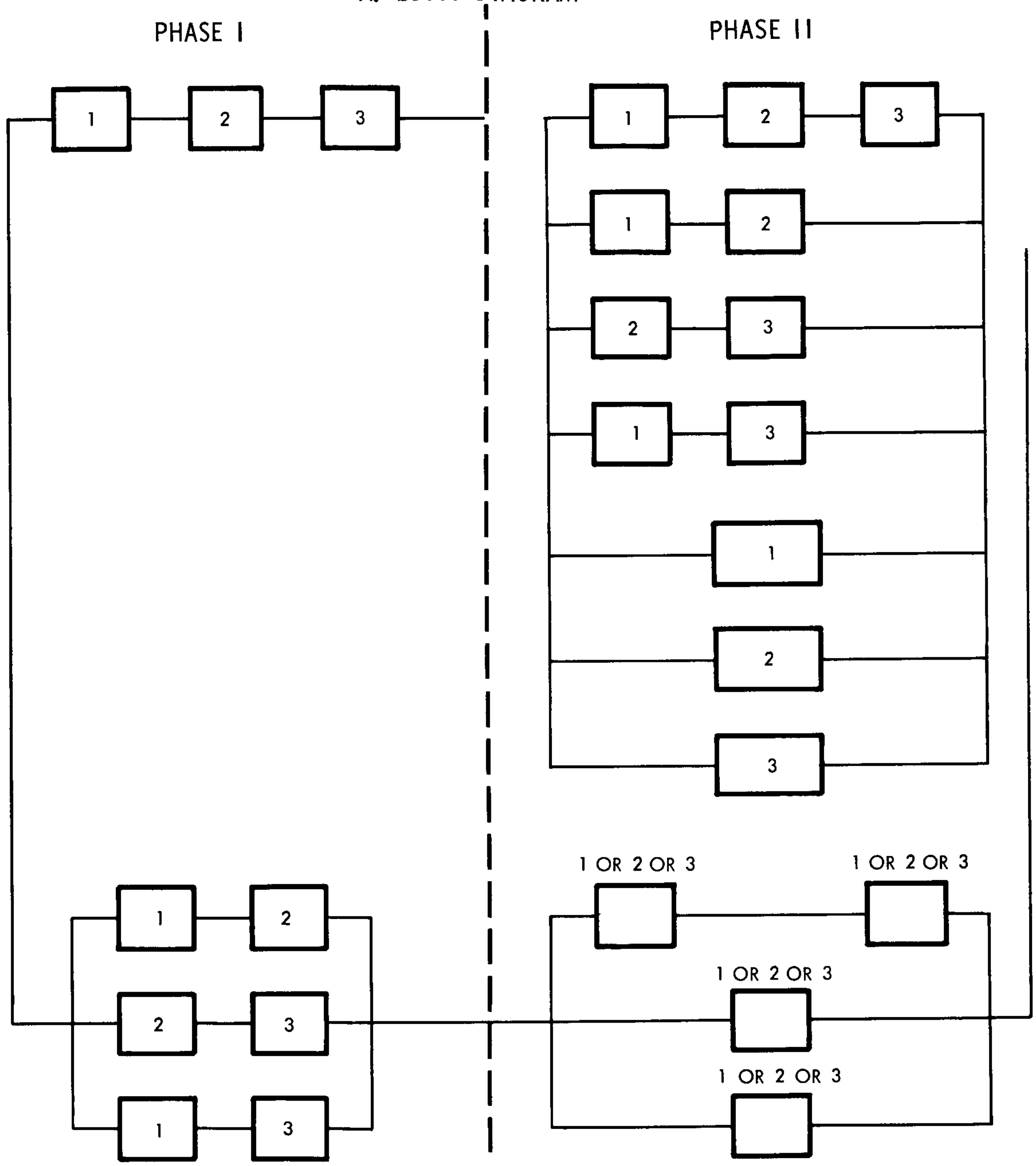
Single Cell Failure Analysis

An analytical study has been completed which utilizes the failure reports compiled during the various development tests on Configuration A fuel cell. The purpose of the study was to establish the prevailing failure trends and to provide frequency versus failure mode characteristics (Table 18). The data in Table 18 was obtained from single-cell, multi-cell, and module test runs. Further reduction of the data will enable the S&ID Reliability group to establish any existing differences between the failure mode effects analysis and the actual failures encountered during the performance runs. The failure data used includes single cell, multiple cell stack, and complete powerplant test results.

Inverter

The latest reliability prediction for the inverter is estimated by Westinghouse to be 0.9668 based on a mission of 336 hours. This is a

A. LOGIC DIAGRAM



B. MATH MODEL

$$R_{MS} = \left\{ \left[R_1^3 \right] \left[R_2^3 + 3R_2^2 (1-R_2) + 3R_2 (1 - R_2)^2 \right] \right\} +$$

$$\left\{ \left[3R_1^2 (1 - R_1) \right] \left[R_2^2 + 2R_2 (1 - R_2) \right] \right\}$$

$$R_{MS} = (R_1^3)(3R_2 - 3R_2^2 + R_2^3) + (3R_1^2 - 3R_1^3)(2R_2 - R_2^2)$$

Figure 17. Fuel Cell Mission Success Diagram and Model

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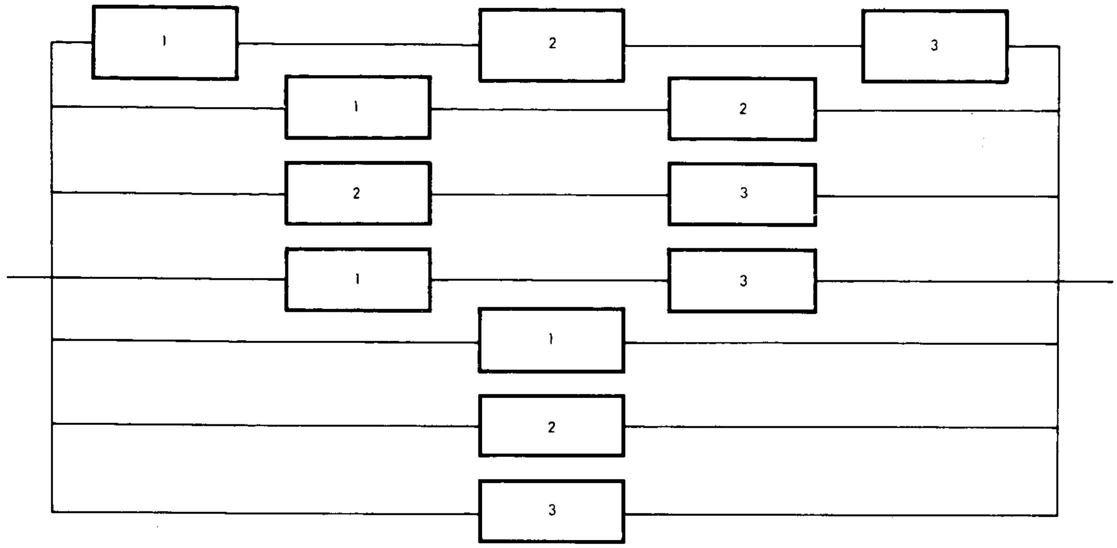
A. LOGIC DIAGRAM



B. MATH MODEL

$$R_{CS} = R^3 + 3R^2 (1 - R) + 3R (1-R)^2$$

$$R_{CS} = R^3 - 3R^2 + 3R$$

Figure 18. Fuel Cell Crew Safety Diagram and Model

considerable increase over the previous estimated reliability of 0.9427, and is due primarily to updated failure rate data.

During this period, Westinghouse, at the direction of S&ID, thoroughly inspected all critical components (i.e., transistors, diodes, resistors, capacitors, magnetic components, etc.). This 100-percent inspection was mandatory because of the criticality of the components incorporated in the inverter. Sampling inspection was ruled out primarily because of the possibility that a noninspected borderline critical part might be incorporated in the inverter and eventually cause the inverter to fail thus jeopardizing mission success and crew safety.

During this period, Westinghouse informed S&ID that the inverter overcurrent trip circuit, which removes the inverter from an overloaded ac bus, is designed in such a manner that a failure of its sensing lamp in the command module renders the circuit inoperable. A study was performed on the overcurrent trip circuit and the results of this study indicate that the sensing lamps are of a quality sufficient to meet the Apollo reliability requirements.

[redacted]

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Table 18. Fuel Cell Electrode Assembly Failure History

Failure Data Log					Significant Failure Modes														
Verbal Notice No.	Report No.	Failure Date	Analysis Date	Corrective Action Status	Void In Diaphragm (Short)	Cell Ballooning (Short)	Ni Sludge In Diaphragm Area (Short)	Tube Plugging O_2	Tube Plugging H_2	Defective KOH Seals (Short)	Cell Short Due To Diaphragms Touching	Cracked Sinter O_2	Cracked Sinter H_2	Cell Short Due To Presence Of Electrical Conducting Impurities	Ruptured Sinter (Open)	External Short	Sinter Flooding	Dendrites	Cause Unknown
1	2225	8-1-63	10-10-63	Design change in progress		Cell No.1													
1	2254	8-12-63	10-10-63	Design change in progress		Cell No.3													
1	2255	8-16-63	10-10-63	Design change in progress		Cell No.6													
2	2311	9-12-63	10-10-63	Design change in progress						Cell No.19									
3	Missing																		
4	2360	9-25-63	10-23-63	Improved inspection procedure						Cell No.16									
4	2361	9-25-63	10-24-63	No specific corrective action at present		Cell No.16													
4	2363	9-25-63	10-23-63	No corrective action															Cell No.18
5	2380	10-3-63	10-28-63	Process change						Cell No. unknown. Failure report missing									
5	2454	10-2-63	Missing																
5	2455	10-6-63	10-31-63	Change purge technique						Cell No.14									
6	2473	10-13-63	11-7-63	Design change						Cell No.17									
6	2475	10-14-63	11-7-63	Handling procedure change		Cell No.20													
6	2480	10-15-63	11-7-63	Design change			Cell No.26												
7	2492	10-18-63	Missing																
8-13	Missing																		
16	2677	12-18-63	1-15-64	Design and process change	Cell No. 15+			Cell No.15+											
16	2688	12-23-63	Missing																
16	2704	12-19-63	1-13-64	Design and process change				Cell No.31											
17	Missing																		
18	2738	1-6-64	1-28-64	Design and process change				Cell No.31											
18	2715	1-2-64	1-28-64	Process inspection and new material									Cell No.23						
19	2726	1-9-64	2-4-64	Process change							Cell No.3								
19	2728	1-11-64	2-4-64	Process change								Cell No.13							
19	2752	1-13-64	2-4-64								Cell No.30								
23	Missing																		
24	3005	2-13-64	3-11-64	Improved design being tested				Cell No.11											
25	3008	2-21-64	3-16-64	Design change	Cell No. 18+	Cell No. 18+	Cell No. 18+												
25	3007	2-22-64	3-16-64	Design change	Cell No. 15+	Cell No. 15+	Cell No. 15+												
27	3101	3-6-64	3-26-64	Change inspection criteria	Cell No. 8+	Cell No. 8+													
28	3113	3-4-64	3-31-64	Design change										Cell No.12					
32	3164	4-14-64	5-5-64	Change in inspection analysis								Cell No. 7							
34	3224	4-27-64																	
35	3260	4-25-64	6-3-64	Scheme III electrode in effect														Cell No.11	
35	3261	4-25-64	6-3-64	Scheme III electrode in effect														Cell No.10	
44	3450	7-2-64	7-28-64	Improve sinter integrity								Cell No.31							
Failure Frequencies					4	8	3		4	5	2	3	1	1				2	1
Percentage Breakdown					11.76	23.50	8.80	11.76		14.70	5.80	8.8	2.9	2.9				5.8	2.9

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Raw test data on the subject lamps gives an MTBF of 600 to 1200 hours. A pessimistic MTBF of 500 hours was used to calculate the reliability of the lamps. It was assumed that the lamps will be operating for 30 minutes. The actual operating time is closer to 15 minutes, however, assuming the indicated lamps will be checked out for approximately one minute each day of the 14-day mission. Using the above criteria, and considering the fact that there are two redundant indicator lamps in the circuit, the reliability of a single lamp is 0.999 and the reliability of the redundant combination is 0.999999, which is considered adequate.

Power Distribution

As a result of NAA and NASA coordination, an error was discovered in the Phase C logic diagram, Figure 3-7, of the Eighth Quarterly Reliability Status Report, SID 62-557-8. Information is given concerning the relationship between the main dc busses and the inverters. As stated, inverter 1 is connected to main dc bus A only, inverter 2 is connected to main dc bus B only, and inverter 3 may be manually connected to either bus A or bus B through a common switch. This bus-inverter relationship applies to all phases of a lunar mission. The corrected and updated Phase C logic diagram is shown in Figure 19.

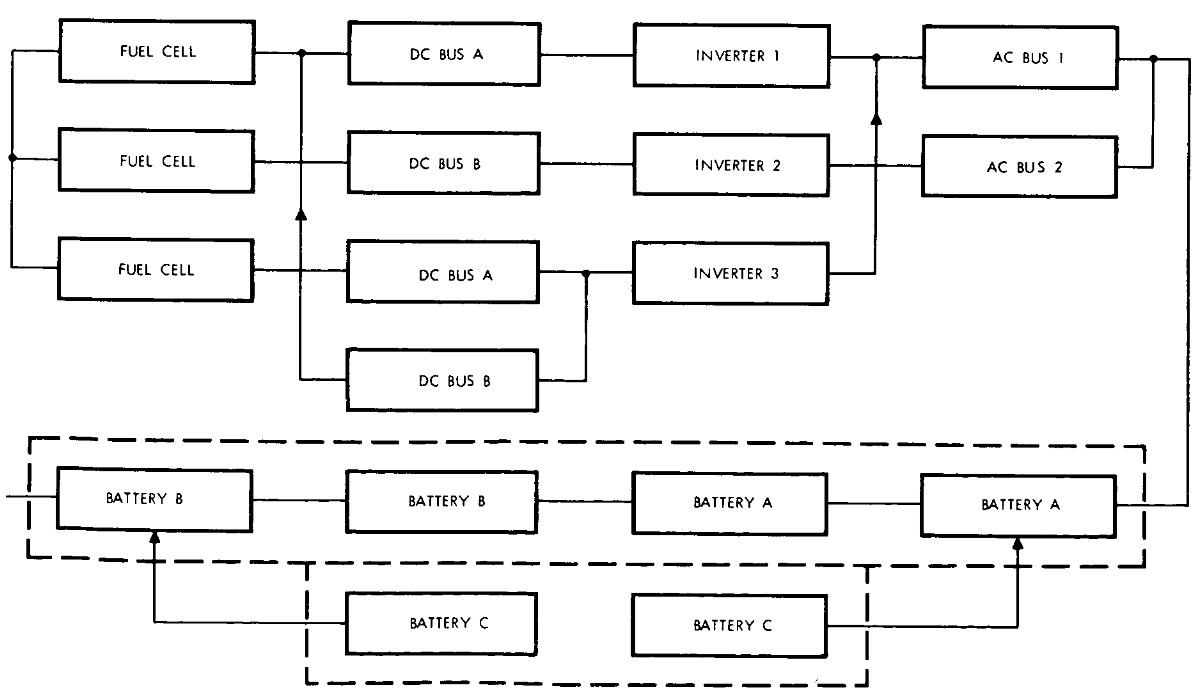

Figure 19. Power Distribution Phase C Logic Diagram

Quarterly effort has been expended in preparation of a power flow diagram for Boilerplate 14 which will be utilized in the preparation of a logic diagram, reliability diagram, single point failure analysis, failure mode analysis, and design analysis of the power distribution system.

Power flow is being traced from generation at fuel cell or battery through intermediate components, circuit breakers, switches, and relays to the component of final utilization. In this manner, any particular path may be analyzed to find single-point failures, and any particular component may be analyzed for its failure modes under imposed operating conditions and environments. Reliability numbers may be assigned to components in regard to operational life and/or cycle life, and total reliability of any path may be summarized with a minimum of effort. A logic diagram indicating all redundancies and single-component failure points also may be derived with a minimum of effort.

It is expected that the primary flow diagram for Boilerplate 14 will be applicable to other vehicles with only minor changes in actual paths and reassignment of reliability numbers to new and/or updated components.

The dc portion of the power flow diagram is complete, and work is continuing on the ac power flow from the inverters.

A report on the evaluation of the rendezvous radar antenna location for the command service modules was completed during this period, and the recommendation was made by Reliability that the most desirable antenna location was Station 268, with Stations 355, 364, and 196 following in that order.

Battery Charger

During this quarter, a major effort has been directed by the supplier toward (1) purchasing high-reliability electronic components for use in the battery charger and (2) breadboard testing. The breadboard was tested in order to verify that the high-reliability components incorporated in the battery charger did not change the electrical characteristics. The battery charger breadboard successfully passed all acceptance tests.

Mission Event Sequence Controller and SM Jettison Controller

Final negotiations were conducted with Autonetics on an Interdivision Work Authorization (IDWA) for design, development, and delivery of both the MESC and the SMJC for Block I Apollo vehicles. In keeping with the present cost reduction effort, proposed reliability effort was reviewed. The proposed reliability program level of effort exceeded that required by the procurement document. Through negotiations, this level of effort was reduced by approximately 50 percent without reducing the program scope and effectiveness.

Prior to these negotiations, Autonetics was working to a preliminary IDWA authorizing initial design work on the MESC and SMJC. As a result of this work, a preliminary design release was provided for S&ID design review action in July 1964. This basic design was reviewed by Reliability and comments and recommendations were submitted to the Apollo Design Review Board for consideration.

TEST PROGRAM

General Purpose Connector (MC 414-0365)

The PV-type connectors have successfully completed all qualification tests except the revised command module crew compartment environmental design criteria (MCR 619). It is estimated that these tests will be completed by December 1964. The KPD type failed to pass oxidation-humidity tests. A redesign of the grommet has been accomplished and successful completion of all qualification tests (except MCR 619) is expected by 17 October.

Rectangular (DPK) Connectors (MC 414-0148)

Qualification of these connectors is complete except for MCR 619 tests.

Bulkhead Feedthrough (MC 414-0164)

Although design characteristics have been corrected, the qualification program for the feedthrough has been delayed due to use of a faulty potting compound. A satisfactory potting compound is now being used, and qualification will begin 16 September 1964.

Launch Escape Tower Umbilical (MC 414-0067)

New information concerning temperature environment during reentry has necessitated an additional development program to determine if the connector can withstand the environment. If no further design changes are necessary, qualification will begin in October 1964 and will be completed by December 1964. The forward compartment umbilical will undergo qualification at the same time due to similarity of environments (MC 414-0191).

Special Application Connector (MC 414-0233)

Qualification of this connector has been delayed because of manufacturer tooling problems. It has been rescheduled to start 1 October and to be completed by 20 November 1964.

GSE-to-Spacecraft Connector (MC 414-0147)

Qualification procedures and procurement specifications for this connector had to be revised to ensure protection of the connector halves when they are not mated and are mounted on the vehicle. Qualification testing has been rescheduled to begin 1 October and to be completed by 20 November 1964.

Special Purpose Subminiature Connector (MC 414-0061)

The supplier is conducting preliminary development tests on a sealed version of the connector for command module use. The new humidity requirement has made it necessary to redesign the previously unsealed connector. Qualification testing of this connector is not presently scheduled.

Subminiature Connector (MC 414-0409)

Proposals from various manufacturers have been reviewed for the procurement of this connector. Preliminary negotiations with Deutsch Co. are being scheduled.

Fuel Cell (MC 464-0015)

The start of the qualification test program for the fuel cell has been delayed to 1 December, and the estimated completion date now is 1 March 1965. This delay was caused by cost and resulting manpower reductions imposed on Pratt & Whitney during July and August. Additional cost reductions in the qualification program resulted in deletion of off-limits testing and reduced the number of fuel cell powerplants from 4 to 2. This qualification program will be for Block I only. One additional fuel cell powerplant will be tested at a later date to Block II vehicle requirements.

A powerplant design change has been made to improve start-up and shut-down procedures. A valve has been placed in the reactant lines downstream of the pressure regulators to allow a low pressure differential to be maintained during heat-up and cool-down. This valve, closed normally, will be opened during heating and cooling.

Engineering development laboraties at S&ID have tested one powerplant in the new vacuum facility discussed in the last progress report. The test was designed to check out procedures and equipment of the new facility and to determine temperature stabilization times under changing loads and stack temperatures at minimum and maximum loads. The powerplant was on load approximately 12 hours in vacuum with the low load of 563 watts yielding a stack temperature of 377-8 F and a load of 1200 watts yielding a temperature of 403-4 F. Good temperature distributions were in evidence during the test. It was determined that the stack temperature would stabilize after a maximum change in load. Further testing, including system tests, will be conducted when the design change discussed above is incorporated in the powerplants being used for these tests.

Problems still being investigated in the development program at Pratt & Whitney include heat rejection, voltage-load characteristics, and hydrogen pump-separator power. Heat rejection at low power is extremely marginal. Difficulty in sustaining sufficient stack temperature at low load levels remains a problem. Hydrogen pumps built to the new configuration have shown an increase in pump power consumption after prolonged bench operation.

Inverter (ME 495-0001)

The unbalance problem, previously encountered in the test of the two design-verification units, has been corrected by permitting the ripple feedback to be imposed on the free-running oscillator. Other problems encountered in the testing of these two units have been out-of-tolerance electromagnetic interference and excessive acoustic noise generation.

Currently an electromagnetic interference reduction program is being conducted on verification unit No. 2, and acoustic noise tests are being made on unit No. 1. An electromagnetic interference reduction configuration has been established for the prototype units using two filter reactors with added wire shielding.

Acoustic noise tests are continuing on unit No. 1. The "octadic" transformer is the greatest noise generator. Tests utilizing foam encapsulation were found to conduct rather than dampen radiated noise. Impregnation in silicone varnish and encapsulation in flexible compounds is the contemplated corrective action.

Start of qualification tests has been postponed under the new budgetary negotiations. It is expected that the start date will be 1 August 1965.

Battery Charger (ME 461-0002)

Start of qualification tests has been rescheduled for 1 October 1964. This rescheduling is necessary to provide sufficient lead time for procurement of high-reliability components.

Qualification tests have been preceded by the testing of the qualification prototype unit with the intent of providing proof-test history for the production units. The qualification prototype and production units are electrically equivalent, but the prototype unit does not use high-reliability components.

Pyrotechnic Batteries (ME 461-0007)

Testing of four development units is now complete. Testing included slow rate charge, conditioning under various temperatures, and high rate discharge. The data indicate that the battery is capable of limited off-limit operation at 30 F, but that performance is marginal at 50 F with respect to the capacity requirement of 36 seconds run time.

Fabrication of ten production units for qualification tests has been initiated. Start of qualification testing is scheduled for 1 November 1964.

Storage Batteries (ME 461-0003)

Limited testing has been accomplished at S&ID in conjunction with the battery charger. Tests are scheduled to continue through the next quarter. Qualification tests were started on 3 August 1964, to continue through 1 October 1964. To date, no failures have been experienced.

Motor Switches

Power Transfer Switch (ME 452-0036)

Qualification tests were begun 9 June 1964. One unit failed to transfer during life tests at 160 F due to epoxy obstruction in the braking mechanism. Another unit failed to transfer when the brake lining did not adhere to the brake shoe. Both of these were established as quality control deficiencies. The supplier established additional inspection points in the assembly and cleaning processes to assure the preclusion of any further epoxy obstruction or contamination of the bonding surfaces.

Two other units exhibited excessive transfer time, on the initial cycle only, during post-humidity functional checks. Several exploratory tests were conducted at the supplier's facility in an attempt to repeat the failure. All subsequent measurements thereafter were within specification requirements. The excessive transfer condition could not be repeated. The supplier has been instructed to perform a tear-down investigation in an effort to locate the reason for the excessive transfer time on the initial cycle. The test setup equipment and wiring also will be checked.

Power Overcurrent Switch (ME 452-0038)

The start of qualification testing has been rescheduled to 25 September 1964.

RCS Transfer Switch (ME 452-0044)

The qualification test units, originally rejected by the Air Force inspector because of noncompliance with the NASA soldering specification, were cleared for qualification testing starting 15 June 1964 after a NASA waiver to the rejection was received. Testing was successfully completed on 24 July 1964 without any failure incidents.

Motorized Relay Switch (ME 452-0045)

During qualification testing, which started 13 July 1964, two units tested for two hours at 65 F showed a contact voltage drop in excess of the 100 millivolt requirement, and one unit failed to transfer normally upon application of 32 vdc. The switches had transferred normally at 28 vdc immediately prior to the failure.

In the case of the high-contact voltage drop units, the supplier has not supplied conclusive data regarding cause of failure. Certain residues and discolored substances found on contact pins currently are being analyzed chemically to determine failure cause and possible corrective action.

Failure to transfer at 32 vdc occurred when, due to the low temperature, the normal slide-fit of the motor brush assembly resulted in an interference fit, thus keeping the brushes from proper contact on the commutator. To preclude recurrence, the supplier has revised pertinent drawings to respecify the type of fit required. Continuation of the qualification tests has been withheld indefinitely, pending resolution of the above failures.

Overcurrent Relay Switch (ME 452-0055)

Development tests have been completed and qualification tests are due to start on 1 October 1964. No significant problems have been encountered. Minor circuit changes and dimension changes are currently being considered, which conceivably could affect the qualification start date.

Motor Switch Failure Analysis

During manufacturing, functional checkout of a Boilerplate mission sequencer and two Boilerplate 23 tower sequencers on ME452-0045 motor switch in each of these units exhibited high contact resistance. The readings observed on contacts of each switch did not meet the requirement that contact voltage drop across closed contacts shall not exceed 100 millivolts at rated current, 15 amps, when measured at the terminals. In two cases, efforts to duplicate the out-of-specification condition proved unsuccessful. However, one switch continued to exhibit excessive contact resistance on successive tests, and further analyses were initiated. Numerous voltage-drop tests were conducted on other contacts of the switch to determine the extent of the problem. It was noted that the high voltage drop only occurred on contacts B1-B2. The switch was returned to the supplier, Kinetics Corporation, for a supplier failure analysis. Tests at Kinetics isolated the discrepant area to the B1 pin and socket. Visual examination showed deposits of foreign matter on the pin end and on the socket entry areas. Cross sections of the sockets were made to determine seating of the ball socket, leakage of solder flux, and any additional residue internal to the socket. Results of the cross section found the socket ball was seated, and positive evidence of solder flux existed at the solder ball interface. Kinetics attributed the increased contact resistance to the development of a resistive film on the open pin and socket. It was Kinetics opinion that the compounds/mixtures which produced these films were flux[1] and/or gases from the epoxy hardener[2] in combination with the lubricant[3] and/or their effect on beryllium copper.[4]

The contact voltage-drop problem was reproduced at Kinetics by presence of a mixture of Cramolin and solder flux on contacts. Exposure of this mixture to temperature (250 F) drove off volatile components, leaving residues which caused an increase in voltage drop. After several cycles, deposits appeared to be displaced, and voltage drop decreased. Expanded testing by Kinetics revealed that solder flux appeared to be the greatest contaminant factor when combined with other materials. Evaluation of Anderol as a lubricant indicated little or no residue was found after temperature cycling, where considerable residue was observed with Cramolin.

Kinetics corrective action plan indicated all subsequent production will be assembled with gold plated contacts, and with tighter control on the removal of solder flux from the switch contacts during final assembly. Anderol will be used as the lubricant.

Similar tests were performed on two groups of ME452-0045-type motor switches. Group A consisted of four switches that had not previously been installed in any sequencer unit and subsequently had not exhibited any high

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[1] Flux from solder joint of lead-in wire and contact socket

[2] Epoxy hardener used for potting semiconductor devices to boards

[3] Lubricant, Cramolin, used to lubricate the pins and sockets

[4] Beryllium copper metal of the contact pins and sockets.

[redacted]

contact resistance. Group B included four switches that had been installed in a deleted Boilerplate 16 mission sequencer and had exhibited high contact resistance. The switches of Group A were submitted to a series of environmental stresses which included a 3-g sinusoidal vibration sweep, wires soldered to external terminals of contact pairs, and then were subjected to a low temperature test. All four units stayed below the 100 millivolt maximum at seven current levels during voltage-drop tests performed before and after each of the environmental conditions. However, one unit failed to cycle completely with an input of 32 vdc at -65 F. Kinetics found one pin and one socket (common lead) in the motor circuitry failing to make contact, thus preventing operation of the motor. This particular unit had been timed improperly, thus allowing discontinuity to occur. Kinetics' explanation was that the unit was an inspection escapee. No change was recommended, since existing procedures normally will detect the problem.

The switches of Group B were submitted to a similar series of environmental stresses and analytical tests. With 15 amperes maximum rated current applied, several contacts of all units failed to meet the 100-millivolt maximum limit. The Quality Engineering Laboratory concluded that the high resistance across the contacts points is primarily a result of the heavy concentration of Cramolin, used to lubricate the pins and sockets, and the presence of a dark amorphous substance on several contacts. Infrared spectrographic analysis of this dark amorphous residue showed absorption bands corresponding to carbonyl among other major constituents, which were identified as a hydrocarbon oil residue. Since Cramolin (sperm oil lubricant) is composed of esters of long-chain fatty acids, the presence of the carbonyl peak probably is due to a decomposition of Cramolin with an impurity in the atmosphere gas or residue of a precleaning process.

Analysis of the protective atmosphere gas inside one of the switches revealed a water content of 4.6 percent and the presence of 21.7 percent of chlorinated hydrocarbons, as well as 63.2 percent of the primary gas, nitrogen. It is significant to note that trichloroethylene, used throughout the manufacturing process as a cleaning solvent, will attack most plastics, including the epoxy used in the laminated board on which the pins and sockets are mounted in this switch. It also should be noted that no evidence of flux contamination was shown in any of the analyses performed on any of the contaminants found in an opened switch.

As a result of the findings, the Quality Engineering Laboratory made the following recommendations:

1. The use of Cramolin as a lubricant should be discontinued.

2. The use of PR-380-M, a two-part black Thiokol Chemical Corporation liquid polymer used as a sealant should be discontinued.

3. The use of trichloroethylene as a cleaning solvent should be discontinued.

Kinetics has changed to Anderol as a lubricant. Mixing and application procedures relative to the second and third recommendations have been reviewed, updated, and/or revised by Kinetics.

ENVIRONMENTAL CONTROL

SUMMARY

Major reliability activity on the environmental control subsystem during the report period consisted of subcontractor qualification test program reorientation for cost reduction and deferment, preparation of logic diagrams for the Reliability Flight Support Report on Boilerplate 14, and a special study on post-landing ventilation systems. In addition, a status check was conducted on open action items from two design reviews.

QUALIFICATION TEST PROGRAM REDIRECTION

A major cost reduction in the qualification of the environmental control subsystem by AiResearch was implemented during the quarter. Component and system criticality for manned and unmanned flights to support Block I and Block II vehicles was used as the criterion for the program reduction. Criticalities were defined as Category I, crew safety essential, Category II, mission success essential, and, Category III, components or systems failures having no effect on crew safety or mission success.

Every component and system was evaluated on functional requirements to meet the various vehicle mission objectives for manned and unmanned flights in Block I and manned flights in Block II. Assignments of criticality rankings were then made for each component and system, and an informal report was transmitted to the Qualification Review Board. With this information, the Qualification Review Board determined the minimum sample size of components or systems in Group I, II, or III qualification testing required to support Block I and Block II vehicles .

ANALYSIS

To support the formulation of the Reliability Flight Support Report for Boilerplate 14, logic diagrams on the ECS were prepared. The logic diagrams, in addition to reflecting functional operations applicable on Boilerplate 14, also denoted functional applicability to the ECS on Spacecraft 009. This was necessary because Boilerplate 14 will simulate and support the mission requirements for Spacecraft 009. The logic diagrams will be included in the Reliability Flight Support Report.

SPECIAL STUDIES

Informal analyses of proposed post-landing ventilation systems were prepared to support design engineering effort on the post-landing ventilation study plan and its implementation, and to support engineering briefings at Houston.

Two design concepts for the post-landing ventilation system were considered for reliability analysis: a water-cooled garment and cabin ventilation, and cabin ventilation only. The predicted reliability values for the two systems, based on mean failure rate data from the AVCO handbook, are 0.99193 for the water-cooled configuration and 0.9996 for the cabin-ventilation-only configuration. The time considered was 48 hours. These values, together with their respective logic diagrams, were incorporated in the briefing to NASA on 28 July 1964 at S&ID. Further work has been held pending analyses for reduced environmental criteria by NASA.

DESIGN REVIEW ACTION ITEMS STATUS

Design Review No. 18 considered the following circuits of the ECS: pressure suit, oxygen supply, and CM pressure and temperature control. Action items and status of assigned problems resulting from the design review are as follows:

1. CO_2 Absorber Bypass Control

   The board recommended that Design Engineering consider incorporation of cutoff control in the CO_2 absorber bypass line for emergency mode.

   Status - The CO_2 bypass has been deleted. Therefore, there is no need for a cutoff control.

2. CO_2 Absorber Unit (item 1.15) Release Mechanism

   a. Clarification of the override possibility of the poppet-type bleed valve in the CO_2 absorber unit housing is needed to improve reliability. The bleed valve is being rotated 180 degrees to be independent of the cover release handle. The bleed valve poppet will now be manually depressed to equalize pressure between the canister and the CM environment.

b. Determination that the release mechanism can be operated by a gloved hand without undue restriction is needed.

Status - Closed. The CO_2 canister on the breadboard model demonstrates that this is feasible.

3. Redundant Valve at CM Main O_2 Supply Line

One of the check valves (item 4.25) located in the main O_2 supply line can fail in an undetectable open position. Failure would allow catastrophic loss of both O_2 storage tanks if a leak in the SM of the same O_2 line were to occur.

Status - Closed. Since this was determined to be a second order failure, no action will be taken but it will be considered during future system changes.

4. ECS Integrated System (Breadboard) Test

The board recommended that a joint action study review be made by the ECS Test group and the Crew Systems group to establish a method for the simulation of work tasks in the "man-rated" test program.

Status - Closed. The proposal was rejected by NASA and Engineering management as not being within scope of the proposed test program during manned tests.

Design Review No. 19 considered the water supply circuit and the water-glycol circuit of the ECS. Action items and status of assigned problems resulting from the design review are as follows:

1. The entire water supply subsystem was reviewed to ensure that maximum design pressures on components and piping are compatible with the water pressure being supplied by the fuel cell units.

Status - Closed. Maximum fuel cell water outlet pressure of 63 psia is the proof pressure for the ECS water supply subsystem components.

2. Line resistance was studied to ensure that the water (from fuel cell units) will fill up the water storage tanks before it can be relieved by the water pressure relief valve (item 5.23).

Status - Closed. Pressure drop analysis of tubing to the storage tank was made and found to be well below the water pressure relief valve setting of 36 psia.

3. ECS Design is to investigate a method for preventing gas entrainment in the water accumulating system and is to check the pressure compatibility of the suit evaporator water inflow control valve (item 5.5).

   Status - Closed. Subcontractor tests indicate that the use of porous materials in the water accumulating system prevents the passage of gas but allows water to pass at a low delta pressure. The proof pressure of the water inflow control valve (item 5.5) is 60 psig. Normal operating pressure is 25 (+2, -0) psig.

4. ECS Design should investigate methods of removing entrained gas in the water-glycol system to prevent pump cavitation during the GSE fill-purge operations.

   Status - Open. S&ID/GSE and the subcontractor have arrived at a "theoretical" solution, but testing will be required. This will be re-reviewed during the application review to be conducted when test data is available.

5. A joint study review should be made between ECS design, GSE, and Reliability to determine that the water-glycol components designed for "maximum operating pressure" are compatible with the GSE checkout pressure.

   Status - Closed. The acceptance test procedure for the suit evaporator water inflow control valve, AiResearch Report No. SS-1146-R, specifies a proof pressure of 60 psig, an operational cycling inlet pressure of 25 (+2, -1) psig, and a leakage test inlet pressure of 40 psig. These valves are compatible with system design pressures.

SUBCONTRACTOR MANAGEMENT

During the report period, three monthly progress reports were received from AiResearch. The reports and reporting periods are:

SS-1013R(24)	15 April 1964 through 15 May 1964
SS-1013R(25)	15 May 1964 through 15 June 1964
SS-1013R(26)	15 June 1964 through 15 July 1964

The reliability section in each report was reviewed for quality of information and status of various activities. In general, these reports were found to be deficient in reporting on reliability program tasks. Specific instructions were given to the AiResearch reliability program manager regarding the deficient reports via telephone conversations. The delinquency in performing up-to-date FMEA's, lack of information regarding supplier reliability activities, and lack of information concerning engineering document reviews were cited to AiResearch. S&ID Reliability will continue to maintain close surveillance of this documentation effort.

TEST PROGRAM

As an outcome of the cost reduction effort, the qualification program was established (see program schedule in Figure 20) with the ECS requirements being set at three systems (two at component level and one at system level) to support the first Block I flight, and three systems (two at system level, and one at component level for off-limits testing) to support Block II flights.

Based on these ground rules, the Group II off-limits tests and two Block II Group III system tests have been deferred to fiscal year 1966; Group I burst tests will be performed subsequently on the components used in Block I Group III tests. The Block I Group III mission cycle has been rescheduled to fiscal year 1966, but will be completed prior to the first Block I flight. Since the second mission cycle could not be completed prior to the flight, that cycle was deleted.

A specific hardware utilization plan for the qualification test program was established that deletes the procurement of 88 hardware items. To incorporate this plan, Block I Group I burst testing will have to be rescheduled subsequent to Block I Group III tests. Of the qualification tests listed in procurement specification MC901-0215D, the following have been deleted from Group I:

- Oxidation tests on all components
- Altitude tests on all except components where the ΔP is required for operation
- Noise ratings and acoustic tests
- Sinusoidal vibration

The salt fog, oxidation, and humidity test requirements (MCR 619) have been added to the program for all electrical components located within the CM pressure shell. Additional component deletions from the Group I test program were made by canceling Group I tests redundant to Group III tests, or performed on similar components.

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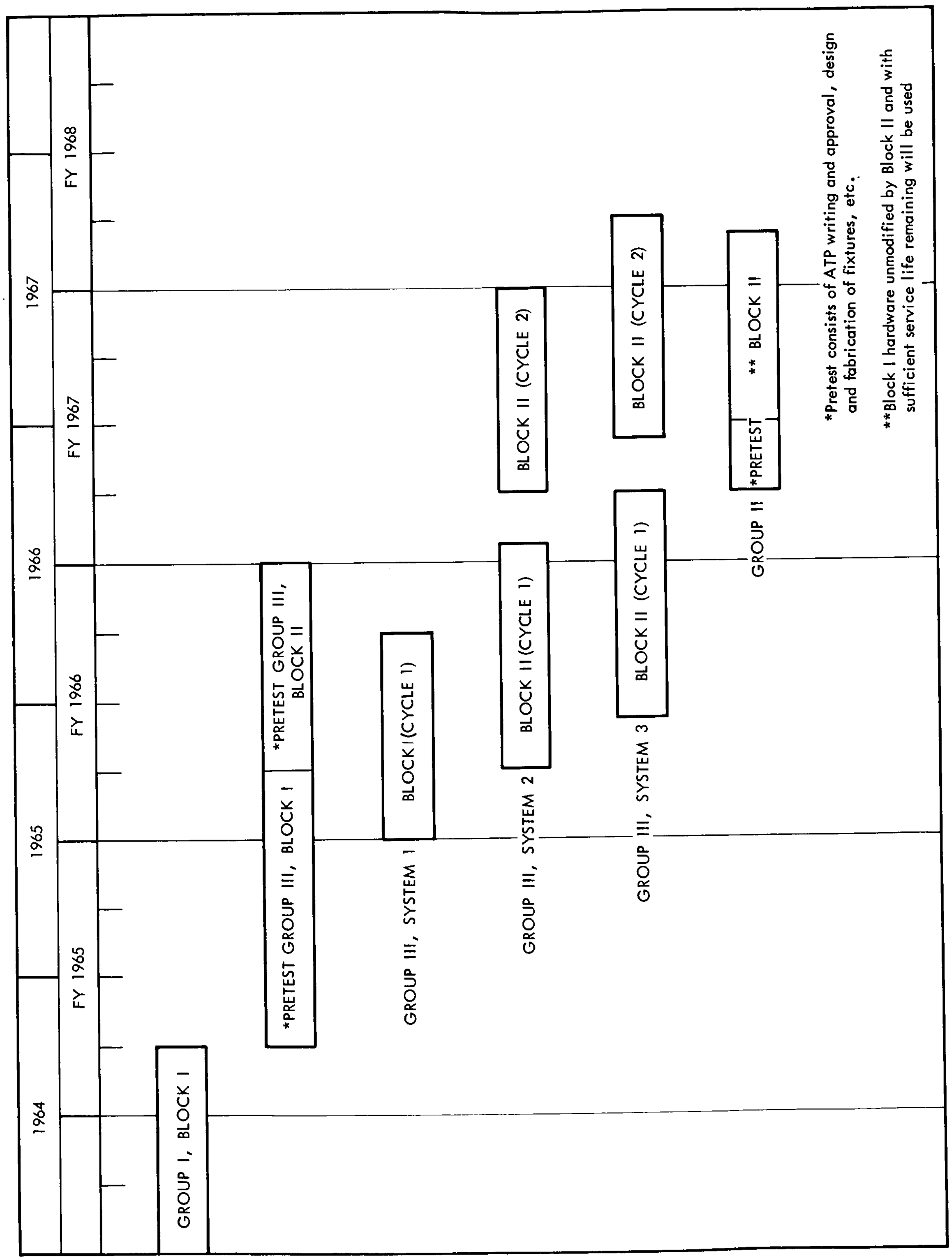

Figure 20. ECS Qualification Program Schedule

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Acceptance Test Program

All acceptance test procedures for Block I hardware have been approved by S&ID. Two complete ECS flight systems have passed the end-item acceptance test and have been delivered to S&ID. Twenty percent of the qualification subsystems have passed the end-item acceptance test and are awaiting qualification testing at the subcontractor.

Qualification Testing

At the end of this report period, 50 of the 60 Block I Group I test procedures had been approved by S&ID. For the start of the next period, there will be 21 different components in the Group I test program. To date, the following components have successfully passed the Group I mission-sequential test portion of the qualification test program:

Glycol shutoff valve
Glycol check valve
Water shutoff valve
Radiator check valve
Cabin blower closure
Water check valve
Debris trap
Backpack supply valve
Glycol fill connection
Water chiller
High-pressure oxygen check valve

Qualification Test Failures

The following components have failed the Group I portion of the qualification test program:

1. Both the cabin recirculating fan 826010-1 and the cabin heat exchanger temperature control valve 850028-1 failed the dielectric strength after humidity. These components are in rework and will be retested under the new salt fog, oxygen, and humidity test requirements of MCR A619.

2. The water shutoff valve and relief valve, 827970-1, failed the leakage requirement during the vibration test. Analysis revealed that contamination was the primary factor. AiResearch is investigating the source of this contamination.

3. The water relief valve, 810340-1, failed the leakage requirement during the high temperature test. The cause of this failure is under investigation.

4. The backpack supply, 828290-1, failed during the burst test. The component was reworked by changing to a hard type O-ring and retested. The component then passed all Group I requirements.

5. The manual metering valve, 827310-1, failed the stop torque requirements. The soft valve stops are being reworked with a harder stop and will be retested.

Development Test Program

Subsystem testing continued during this period on the suit circuit subassembly with the evaporator and a redesigned cycle accumulator. Good results were achieved. Various test runs were conducted with oxygen in the suit loop to check evaporator capabilities. Testing on this subsystem will be concluded during the next report period.

The cyclic accumulator and water pressure relief valve subsystem tests, which were to be concluded during this period, will be continued to permit testing of redesigned components. The rapid action of the cyclic accumulator in expelling the water caused an excess pressure rise in the water system. The test results indicate an orifice in the water line at the accumulator will correct this situation.

The water-glycol solution de-aeration tests were interrupted to investigate air entrapment in the water-glycol pump. Component tests were conducted on a plastic pump to determine if a problem area existed. Tests were then conducted on a production-type water-glycol pump. Results dictated corrective action in the form of a groove in the pump housing. Tests were then conducted that justified the action taken. De-aeration testing was again initiated and showed the need for additional development of the water-glycol pump. The de-aeration testing was again interrupted. These areas will be resolved, and testing will be continued during the next report period.

The S&ID command module steam duct was sent to AiResearch during this report period for testing with the glycol evaporator and backpack pressure valve. Preliminary tests indicated the duct is capable of passing the design requirements. Testing will be completed during the next report period.

Development testing is approximately 92 percent complete. Of a total of 744 planned tests, 672 have been completed, and 16 are in progress. The tests in progress or planned are design verification tests on production-type units.

[redacted]

PLANNED ACTIVITIES

The single-point failure summary and problem summary for the Reliability Flight Support Report for Boilerplate 14 will be completed.

The Design Review Board meetings on the ECS will be supported.

Subcontractor reliability program efforts will be monitored, evaluated, and directed.

Reliability effort on post-landing ventilation system will be resumed as requested by Engineering.

Action items from previous Design Review Board meetings will be followed up.

[redacted]

LAUNCH ESCAPE

SUMMARY

The qualification test programs have been completed for the launch escape and pitch control motors. Qualification testing has begun on the tower-jettison motor, and two motors have been successfully fired.

The test programs for motors of the launch escape subsystem were reviewed in an attempt to reduce expenditures in fiscal year 1965. The review resulted in six motors being deleted from each qualification test program, in addition to the two motors previously deleted.

ANALYSIS

Results of prequalification reliability assessment of the launch motor and tower jettison motor are shown in Section I under Reliability Assessments.

TEST PROGRAM

Twenty launch escape and 22 pitch control motors were fired during the qualification test phase. Qualification programs for these motors and partial performance data are included in Lockheed Propulsion Co. Reports 588-P-25, 588-P-26, and 588-P-27. Six motors were deleted from each program to reduce costs. Three of the four vibration tests were deleted from the launch-escape motor qualification test program. Since all environments and test firing conditions are still covered by the test program, the ability to assess reliability was not considered to be impaired by the deletions.

A boost protective cover was added to the command module structure. This necessitated a change in thrust vector angle for the tower jettison motor that required nozzle redesign, as described in Thiokol Report No. A-223. Five additional development motor firings were considered a requirement to prove this design change; however, the qualification program was initiated after only two of the planned firings (refer to Thiokol Reports A-224 and A-225) because the firings conformed well with anticipated test results. Two qualification motors with the new nozzle design have been fired with satisfactory results.

The pyrogen firings of the tower jettison motor required to verify the integrity of the modified pellet-basket assembly have been completed. Pyrogen retrofit is being accomplished on appropriate boilerplates and spacecraft (refer to Thiokol Report No. A-225).

During a head-end unpackaged drop test of the pitch control motor, the bond between the carbon insert and the nozzle housing failed, causing separation of the carbon from the nozzle housing. This was not termed a qualification test failure; the requirement for this test is that the motor does not explode.

During shock testing of the packaged launch escape motor, the package and Conax connector were damaged at the head end of the motor assembly. The motor slipped within the packaging crate, and it was necessary to replace the connector. The motor was subsequently fired successfully. This occurrence was not termed a qualification failure because the motor's performance was not impaired.

PROBLEM AREAS

Burn-rate variations in propellant mixes of the same chemical composition were demonstrated with a new batch of propellant mix during testing in batch-check motors. The phenomenon, as described in Lockheed Propulsion Co. report 588-P-26, is considered due to the difference in the specific surface area of the iron oxide used. It was necessary to fire batch-check motors with varying ground-oxidizer apportionments to determine the optimum apportionment required to obtain the desired burn rate. Therefore, varying the ground-oxidizer apportionments of each new receival of propellant mix will be required.

After the qualification-testing program for the launch escape motor was completed, it was discovered that the thrust stand had not been calibrated. An analysis is being performed to determine the correction factor, if any, that must be applied to the resulting test data.

PLANNED ACTIVITIES

The initial reliability assessments of data from the subcontractor's qualification testing of the launch escape and pitch control motors will be reviewed.

Motors that are stored during the flight program will be test fired to verify their integrity and to determine any effects from aging. The number of firings required and the time between firings will be determined.

SEPARATION AND PYROTECHNIC DEVICES

SUMMARY

No qualification tests of pyrotechnic devices or separation subsystems were completed during the report period. Development tests are in progress for the canard thruster cartridge, dual drogue disconnect, CSM umbilical disconnect, LEM docking ring, LEM-adapter separation, and different types of splices in the SLA adapter panels. Table 19 presents the status of testing for pyrotechnic devices.

PLANNED ACTIVITIES

During the next report period, the following tests will be in progress:

1. Component qualification tests: standard hotwire initiator and pressure cartridge for propellant valve

2. Component development tests: dual mode bolt, detonator cartridge, booster cartridge, flexible linear shaped charge, shaped charge cartridge, and pressure cartridges for drogue and pilot parachute mortars, forward heat shield separation, circuit interrupter, and canard thruster.

3. System development tests: forward heat shield separation, launch escape tower separation with dual mode bolts, canard thruster and operating mechanism, CSM umbilical disconnect, SLA thruster and take-up reel, and dual drogue disconnect.

No test will be conducted on Block II components or subsystems during the next report period. Qualification tests of the igniter cartridge will begin when qualified initiators are available.

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Table 19. Test Status of Pyrotechnic Devices

Drawing Number	Description	Phases Completed: Design	Development Test	Prototype Qualification	Qualification Test	Used On
ME 453-0009	Standard hotwire initiator, SOS	X	X	X		All boilerplate and spacecraft
ME 453-0009	Standard hotwire initiator, Hi-Shear	X	X			All boilerplate and spacecraft
ME 453-0005	Pressure cartridge, drogue mortar	X	X	X		Boilerplate 12 and subsequent
ME 453-0005	Pressure cartridge, pilot chute motor	X	X	X		Boilerplate 12 and subsequent
ME 453-0005	Pressure cartridge, propellant valve	X	X			Boilerplate 22 and subsequent
ME 453-0005	Pressure cartridge, circuit interrupter	X				Spacecraft 009 and subsequent
ME 453-0005	Pressure cartridge, forward heat shield	X				Boilerplate 22 and subsequent
ME 453-0005	Pressure cartridge, parachute release					Block II
V15-590220	Pressure cartridge, canard thruster	X				Boilerplate 23 and subsequent
ME 901-0595	Pressure cartridge, adapter panel thruster	X				Block II
ME 453-0014	Igniter cartridge, Types I and II	X	X	X		Boilerplate 12 and subsequent
ME 453-0021	Detonator cartridge	X	X	X		Boilerplate 12 and subsequent
ME 453-0022	Booster cartridge, linear shaped charge	X				Spacecraft 002 and subsequent
ME 111-0001	Explosive bolt, single mode	X	X	X	NA*	Boilerplate 6, 12, 13, 15 only
ME 111-0004	Explosive bolt, dual mode	X	X			Boilerplate 23 and subsequent
ME 453-0006	Flexible linear shaped charge	X				Spacecraft 002 and subsequent
ME 453-0024	Shaped charge cartridge, propellant dispersal					Spacecraft 009 and subsequent
ME 901-0612	Explosive train charge					Block II
ME 901-0595	Pressure cartridge, explosively initiated					Block II
	SYSTEMS					
V16-596100	Forward heat shield separation	X				Boilerplate 22 and subsequent
V15-590001	Launch escape tower separation	X				Boilerplate 23 and subsequent
V17-590001	Command module to service module separation	X	X			Boilerplate 12 and subsequent
V17-590001	Umbilical disconnect, command to service module	X				Spacecraft 002 and subsequent
V24-590001	SLA adapter separation	X				Block II
V24-590100	LEM-adapter separation	X				Block II
V24-590004	LEM-service module umbilical disconnect					Block II
not assigned	LEM docking ring	X				Block II
not assigned	LEM docking latches					Block II
not assigned	Service module propellant dispersal system	X				Spacecraft 009 and subsequent
V15-590201	Canard thruster	X				Boilerplate 23 and subsequent
V15-300800	Canard system	X				Boilerplate 23 and subsequent

*NA - not applicable

SERVICE MODULE PROPELLANT DISPERSAL

SUMMARY

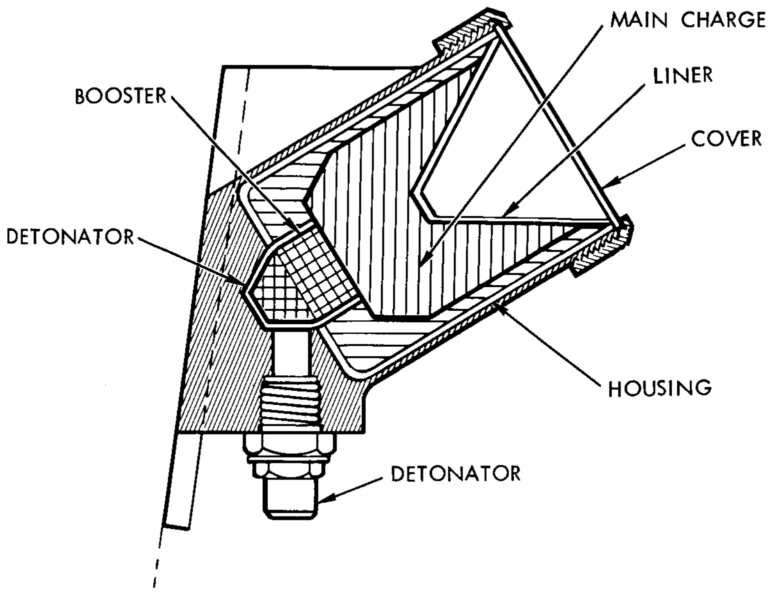
Reliability analysis was initiated on the service module propellant dispersal subsystem. The subsystem is being designed for altitude dispersion of service module propellants to preclude possible ground personnel hazard. Propellants will burn at altitude and will present fewer problems on landing. This subsystem will be activated only in the event of low-range safety hazard caused by the trajectory of the service module after the command module has separated from it. Design consists of four shaped charges, each penetrating two tanks (Figure 21). These charges would be activated by a ground signal with suitable time delays and an interlock for command module separation from the service module.

ANALYSIS

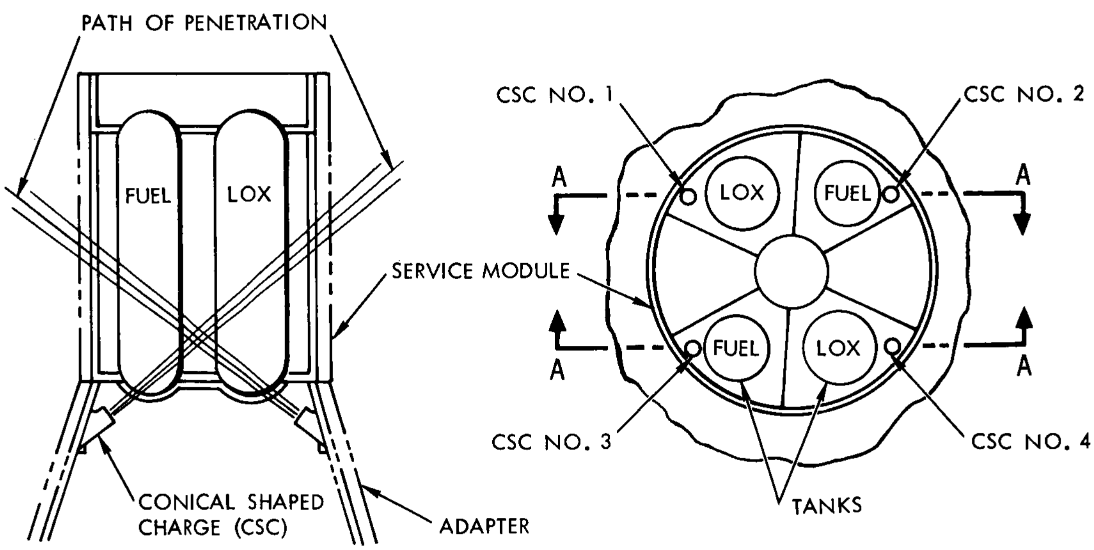
Mission success and crew safety are affected only by the inadvertent firing of any shaped charge. Should this occur, the command module probably would be unable to escape the general conflagration and would be destroyed. Prevention of inadvertent firing is planned by providing redundant electrical equipment for both activation and nonactivation and by ensuring good quality control in the shaped charge material. Extremely high reliabilities have been apportioned for mission success and crew safety (0.9999999 for each) because of the immediate, catastrophic results of failure.

Probability of functioning of the service module propellant dispersal subsystem has been apportioned at a relatively low level (0.9999). This should be readily achievable with current equipment. The probability of functioning is sequential to requiring the function. Since the probability of requiring the function is already low, the probability of protecting ground personnel is very high.

Logic diagrams for the mechanical portion of the SM-PDS have been prepared and are included as Figure 22. The inadvertent firing logic is all serial because of the difficulty in escape of the command module. Function logic shows two redundant groups. For the criteria that a tank must be punctured to disperse propellants in a sufficiently short time, shaped charge No. 1 is redundant with shaped charge No. 2 and shaped charge No. 3 is redundant with shaped charge No. 4.



TYPICAL CONICAL SHAPED CHARGE



SECTION A-A

PLAN VIEW

Figure 21. PDS Schematic

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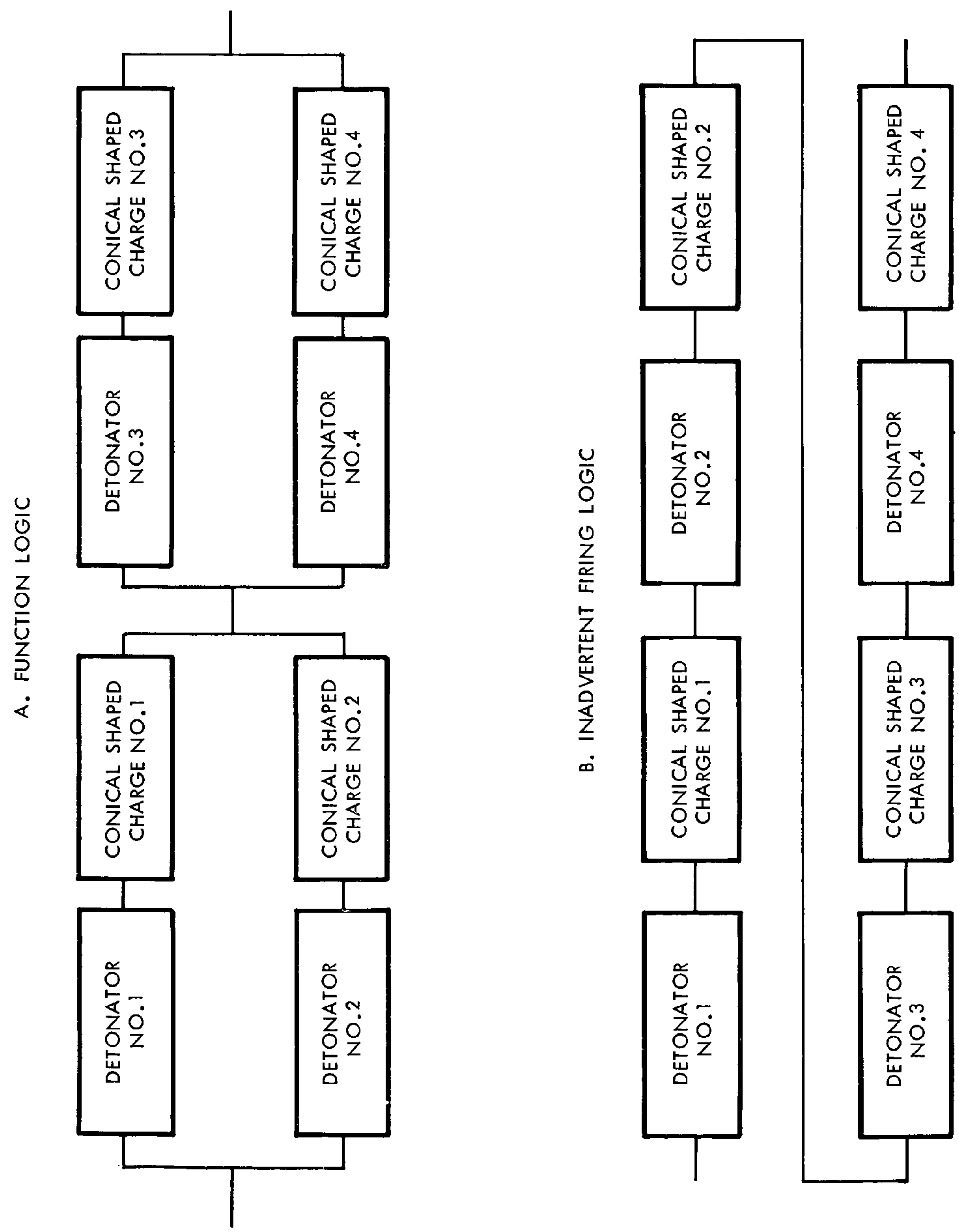

Figure 22. PDS Logic Diagram

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SERVICE MODULE REACTION CONTROL

SUMMARY

The reliability activities during this reporting period encompassed all phases of subcontractor and supplier management. This effort included the review of subcontractor and supplier originated failure mode and effects analyses, identification and traceability exempt parts lists, and failure reports.

Logic diagrams and a single-point failure summary were prepared for the service module reaction control system Boilerplate 14 configuration. The logic diagrams and failure summary appear in the Reliability Flight Readiness report for Boilerplate 14.

ANALYSIS

Mission success and crew safety logic diagrams were revised (Figures 23 through 26) for the SM RCS to reflect present requirements.

SUBCONTRACTOR MANAGEMENT

Reaction Control Engine

A reliability coordination meeting was held with the engine subcontractor during this reporting period. The topics under discussion were (1) the utilization of development test results to determine the risk of proceeding into qualification with a particular engine configuration and (2) the preparation of an identification and traceability procedure. The subcontractor stated that since the proposed qualification configuration was still in a state of design flux, it was impossible to make any meaningful correlation between it and results from previous developmental tests. It was agreed that when the qualification design was established, applicable test data would be analyzed to determine the merits of the particular engine. The subcontractor transmitted a preliminary copy of their identification and traceability procedure with the understanding that formal submittal would occur within a month.

The changes previously requested by S&ID were incorporated into the subcontractor's reliability program plan, and the document was officially approved.

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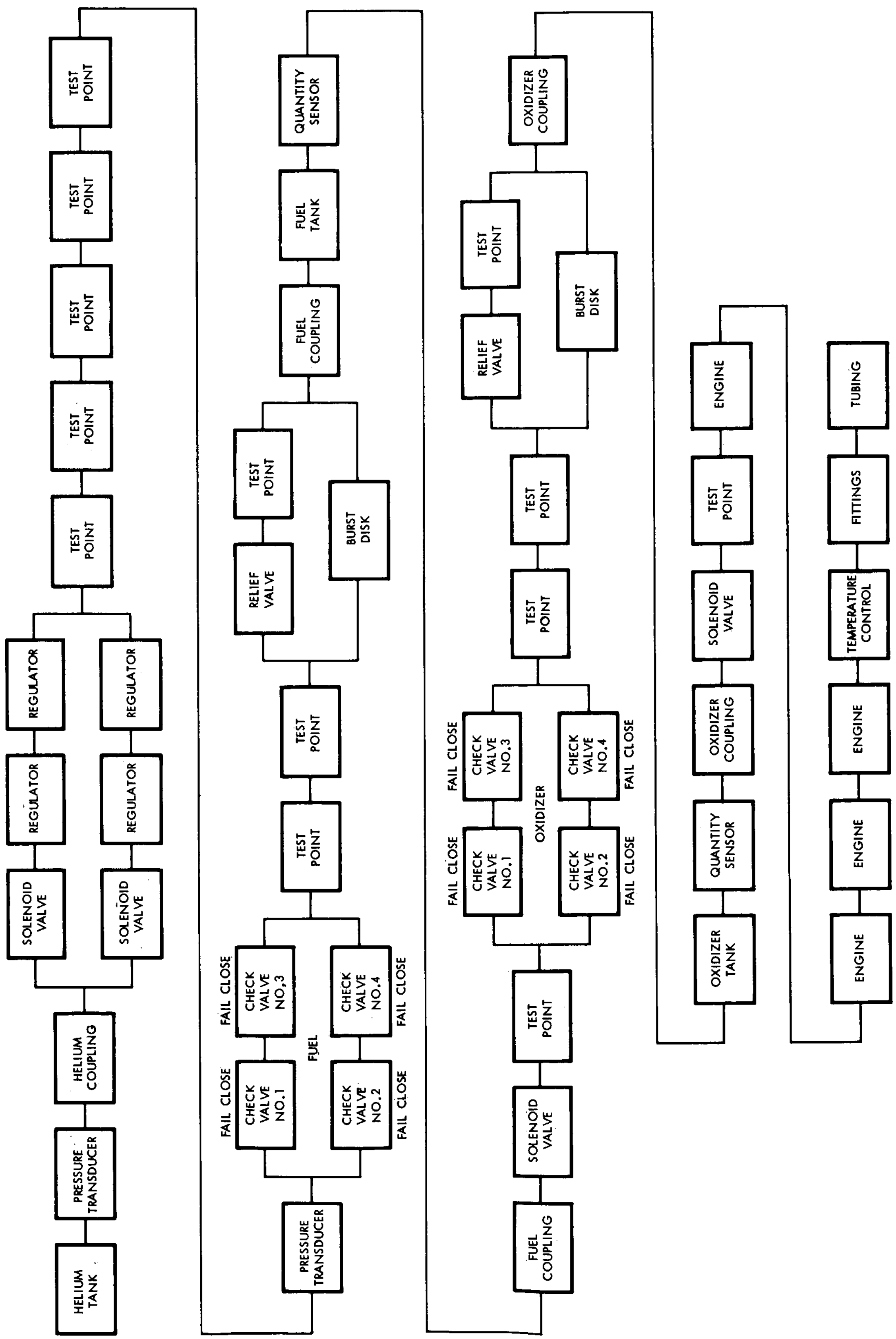

Figure 23. RCS Mission Success Logic Diagram, Module Only

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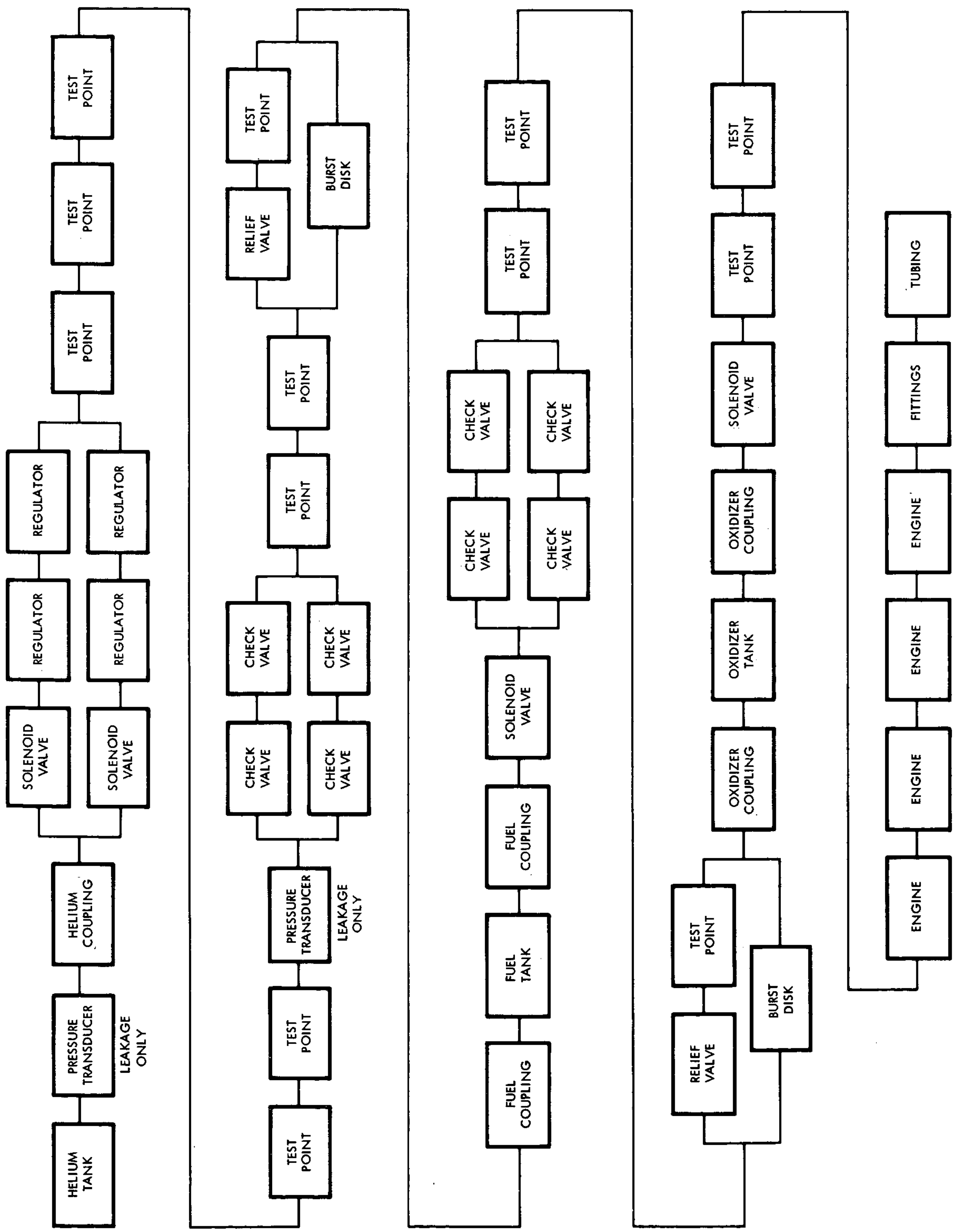

Figure 24. RCS Crew Safety Logic Diagram, Module Only

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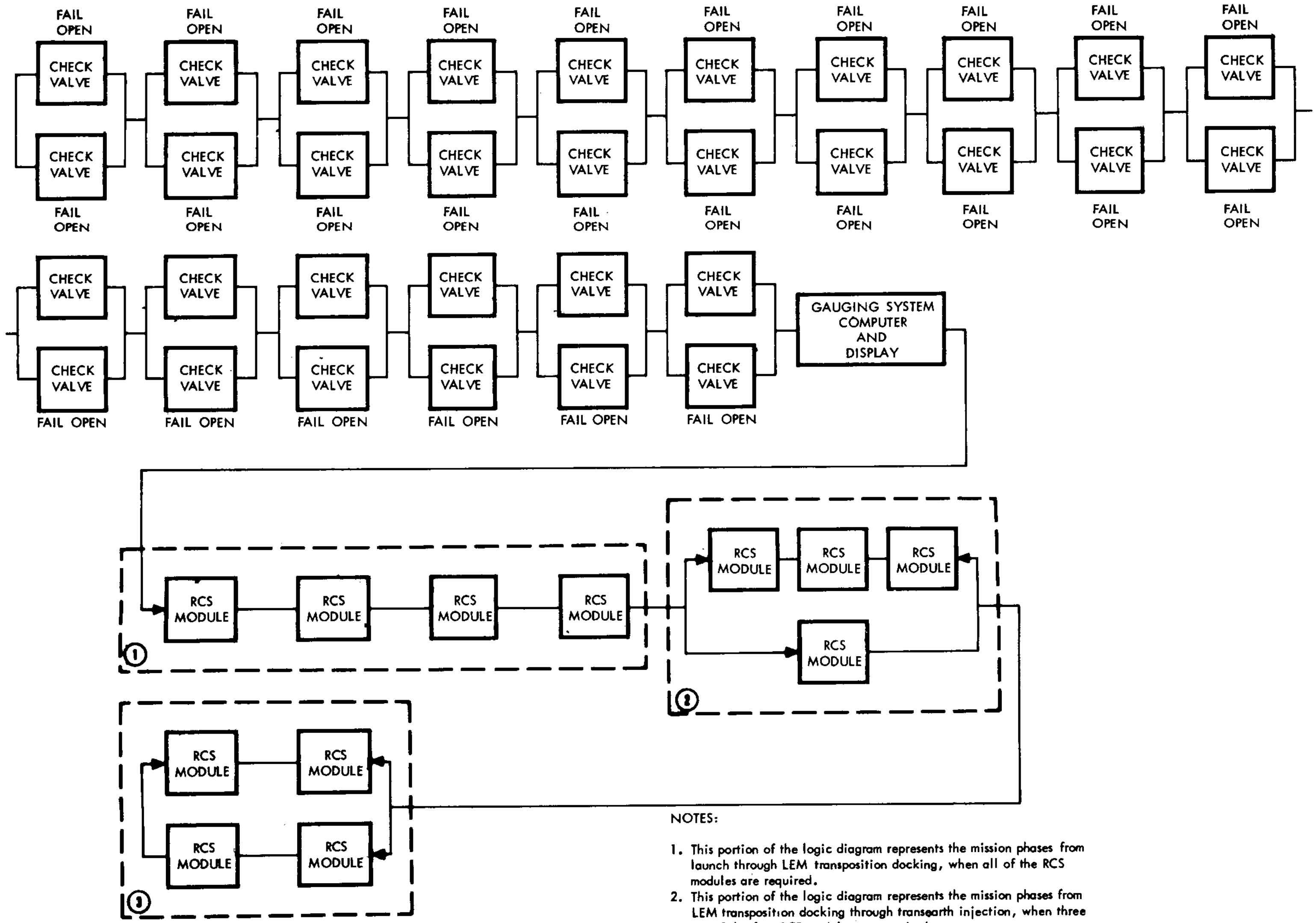
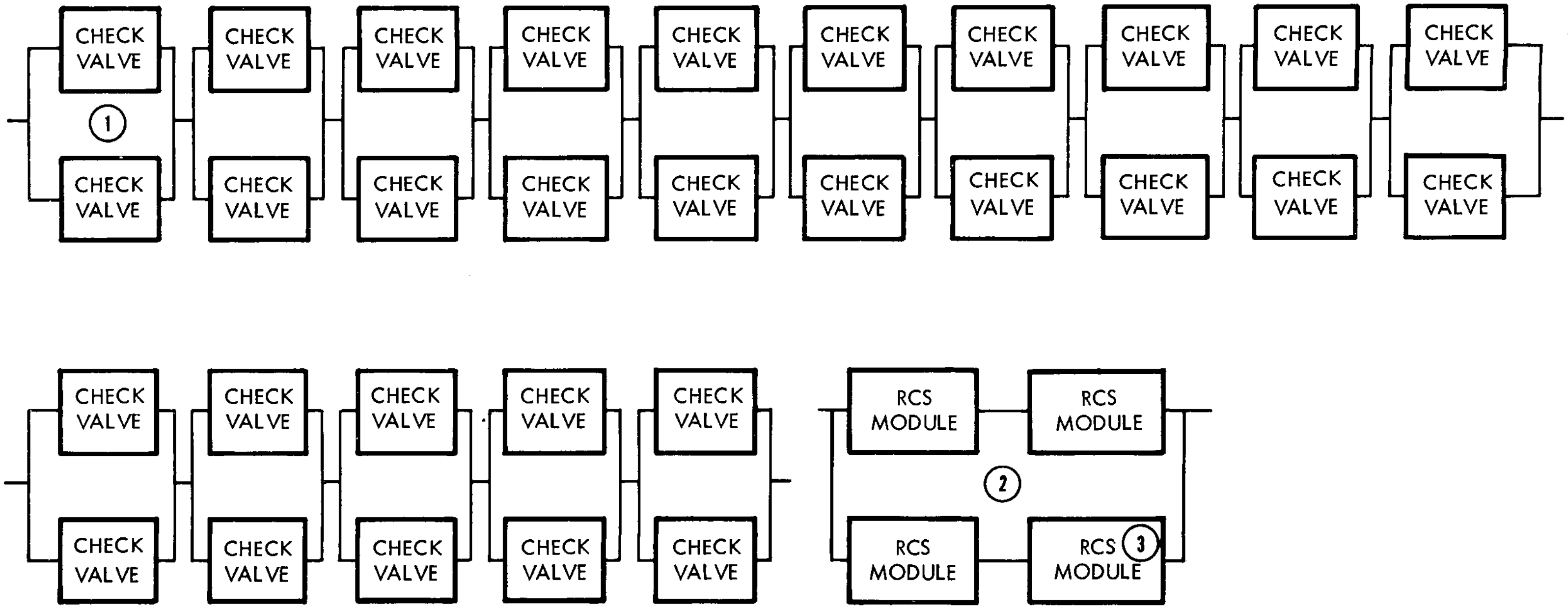


NOTES:

1. This portion of the logic diagram represents the mission phases from launch through LEM transposition docking, when all of the RCS modules are required.
2. This portion of the logic diagram represents the mission phases from LEM transposition docking through transearth injection, when three out of the four RCS modules are required.
3. This portion of the logic diagram represents the mission phases from transearth injection through service module separation, when any two of the RCS modules are required.

Figure 25. RCS Mission Success Logic Diagram, Complete Subsystem

[redacted]



NOTES:

1. The check valve arrangement represent the "fail open" mode of failure.
2. This portion of the logic diagram represents the crew safety logic for the entire mission, when any two out of the RCS modules are required.

Figure 26. RCS Crew Safety Logic Diagram, Complete Subsystem

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Propellant Quantity Gauging Subsystem

Three meetings have been held with the propellant quantity gauging subsystem supplier during this quarter. Two of the meetings were concerned with program reorientation and cost reduction. The third meeting was held in conjunction with the acceptance testing of the propellant quantity gauging subsystem for Boilerplate 14 and dealt with testing procedures and deviations. The most significant deviation granted was a reduction in the system accuracy from 0.5 to 1.5 percent for Boilerplate 14 nonflight application.

The supplier submitted a detailed failure mode and effects analysis. This document was reviewed by S&ID, and its contents were approved.

The previous S&ID recommendations regarding the supplier's identification and traceability Exempt Parts List were incorporated by the subcontractor, and the list was approved by S&ID.

TEST PROGRAM

SM RCS Engine

Design efforts have been concentrated toward a pre-igniter engine configuration concept designed to eliminate ignition spikes at mission conditions. The pre-igniter program consists of two phases: (1) to define and establish the operating limits of the pre-igniter and (2) to establish a qualification configuration engine and to evaluate its performance.

Effort is still being effected to achieve a satisfactory combination between high specific impulse and low chamber temperatures.

Two types of pre-igniter configurations have been tested, a 45-degree slashed cup and a square-end cup. Although both configurations were successful in reducing ignition combustion pressure levels to tolerable values, the slashed cup configuration eroded slightly during steady-state testing. This erosion removed material from a section approximately 1/8 inch wide and 1/16 inch long. Maximum injector soak back temperatures on both development engines incorporating the pre-igniters were unacceptably high at 450 F. Development efforts will continue. Qualification is scheduled to start 2 November 1964 and to be completed on 11 January 1965.

SM RCS Propellant Feed

The three following component suppliers have successfully completed the qualification phase of testing and are preparing to initiate off-limit testing:

[redacted]

1. Lear Siegler-Romec, Test-point coupling disconnects
2. J. C. Carter, Propellant coupling disconnects
3. Menasco, Helium pressure vessel

The four following component suppliers have completed the design verification phase of testing and are preparing for, or have initiated, qualification testing:

1. Apco, Helium check valve
2. Calmec, Pressure relief valve
3. Fairchild-Stratos, Helium pressure regulator valve
4. On-Mark, Helium fill/drain coupling disconnect

Giannini Controls Corporation has initiated design verification testing on components of the propellant quantity gauging system.

Development efforts are being accomplished by three component suppliers:

1. Bell Aerosystems - Propellant tank assemblies
2. Eckel Valve Company - Propellant solenoid valve
3. Sargent-Fletcher - Helium solenoid valve

Bell Aerosystems is experiencing difficulty in achieving an adequate bladder configuration for the SM RCS positive expulsion propellant tank assembly. Expulsion efficiencies have been improved by the modification of the diffuser tube subassembly, but cyclic expulsion requirements continue to be a prime problem. Because of the continuous effect of ply separation upon exposure to propellants, efforts are being concentrated on evaluation of 6-mil, single-ply bladder configurations. An additional design change, the incorporation of a liquid side-vent diffuser tube, was made to facilitate loading in the vertical attitude.

Additional development tests being performed at Eckel Valve Co. and Sargent-Fletcher are described in the CM RCS section of this document.

[redacted]

SERVICE PROPULSION

SUMMARY

Progress has been made toward achieving the reliability apportioned to the bipropellant ball valve for leakage. A new seal configuration has endured 7500 cycles and exhibited zero GN_2 leakage.

Results of analysis indicated that a 90 percent reduction in failures can be achieved in both mission success and crew safety by employing electromechanical ball-valve actuation and sequential operation of the redundant feed channels. A 30 percent reduction in failures for mission success can be expected from sequential operation by using the present hydraulic propellant-valve actuation system.

The thrust-chamber assembly reliability assessment remains virtually unchanged from that reported for the last quarter. Based on sequential analysis of hot-fire data, it is 61 percent at the 50-percent confidence level.

ANALYSIS

Bipropellant-Valve Seals

Five independent tests of a single ball in a bipropellant-valve housing were conducted to evaluate a new short-legged seal design. Results of the testing indicated that the seal tested can survive 7500 cycles, in water at pressures between 5 and 240 psi, and retain a zero GN_2 leakage characteristic. These data demonstrate a leakage reliability of 0.99555 per ball based on the Chi-square test, comparing closely to the apportioned leakage reliability of 0.99827 per ball. Further testing is required to investigate the effects of prolonged exposure to propellants on the demonstrated ability of the seal.

Bipropellant-Valve Actuation

The bipropellant-valve actuation system of the service propulsion system engine was analyzed for reliability. The purpose of the analysis was to provide a numerical reliability comparison between hydraulic-valve actuation and a proposed electromechanical system. In addition, simultaneous operation of the two redundant feed channels was compared with sequential operation. The simultaneous mode requires all eight propellant balls to be operating. The sequential mode requires only four of the propellant balls to be operating and reserves four in the closed position for use in the event a failure occurs in the valves that are operating.

Results of the analysis indicated that sequential operation of the bipropellant ball valves, utilizing electromechanical actuation, would reduce failures in this subsystem by 90 percent in mission success and by 96 percent in crew safety. Sequential operation, utilizing hydraulic actuation, would reduce failures by 31 percent in mission success. Based on these data, appropriate recommendations were made to Propulsion Design.

Several methods of eliminating erratic valve opening are under consideration. As a means of providing greater repeatability of opening transient characteristics, orificing of the actuators is being investigated. Orificing allows opening one of the in-series balls of the bipropellant valve ahead of the other, eliminating the opening time characteristic of one of the balls as a variable and, therefore, decreasing the standard deviation for opening time.

The present two-way shutoff valve design employs a single dynamic seal between the pilot section of the valve and overboard, at the pintle. As a result of joint S&ID-subcontractor design review, the supplier has been directed to develop redundant sealing for the pilot section.

RELIABILITY ASSESSMENTS

Subcontractor activity in reliability assessment has been monitored, and the following direction has been given to provide the most meaningful assessment possible from current test data:

1. The subcontractor was directed to choose the point of greatest change for each new origin in the sequential plot of equivalent mission tests versus failures. This minimizes the probability of making an erroneous decision regarding a true change of population failure rate from observed changes in sample failure rates and eliminates as many nonrepresentative tests as possible from the assessment samples.

2. Figure 27 is a sequential plot of service propulsion system engine reliability based on hot-fire testing of engines and thrust-chamber assemblies. Based on the most current sample, the probability of no mechanical failure as of 10 September 1964 is 61 percent at the 50-percent lower confidence level and 51 percent at the 90-percent lower confidence level. The subcontractor had previously been reporting the highest reliability achieved during the interval between beginning of the sequential plot and each report date. Now, the reliability based on the most recent data is reported. As shown

[redacted]

CALCULATED SEQUENTIAL SLOPE AND INTERCEPT FACTORS

CONFIDENCE LEVEL = 50 PERCENT = (1-B) B = 0.10

P* FAILURE RATE	0.50	0.40	0.30	0.20	0.10	0.05	0.01	0.001	0.0001
RELIABILITY	0.50	0.60	0.70	0.80	0.90	0.95	0.99	0.999	0.9999
h/s, TRIALS INTERCEPT	3.32	4.51	6.46	10.32	21.85	44.88	229.4	2,326	25,000
S, SLOPE	0.4414	0.3490	0.2592	0.1710	0.0849	0.0424	0.0085	0.0008	0.0002

CONFIDENCE LEVEL = 90 PERCENT = (1-B) B = 0.02

P* FAILURE RATE	0.50	0.40	0.30	0.20	0.10	0.05	0.01	0.001	0.0001
RELIABILITY	0.50	0.60	0.70	0.80	0.90	0.95	0.99	0.999	0.9999
h/s, TRIALS INTERCEPT	5.64	7.66	10.97	17.53	37.13	76.26	389.7	3,951	42,474
S, SLOPE	0.3678	0.2871	0.2105	0.1375	0.0675	0.0334	0.0067	0.0007	0.0001

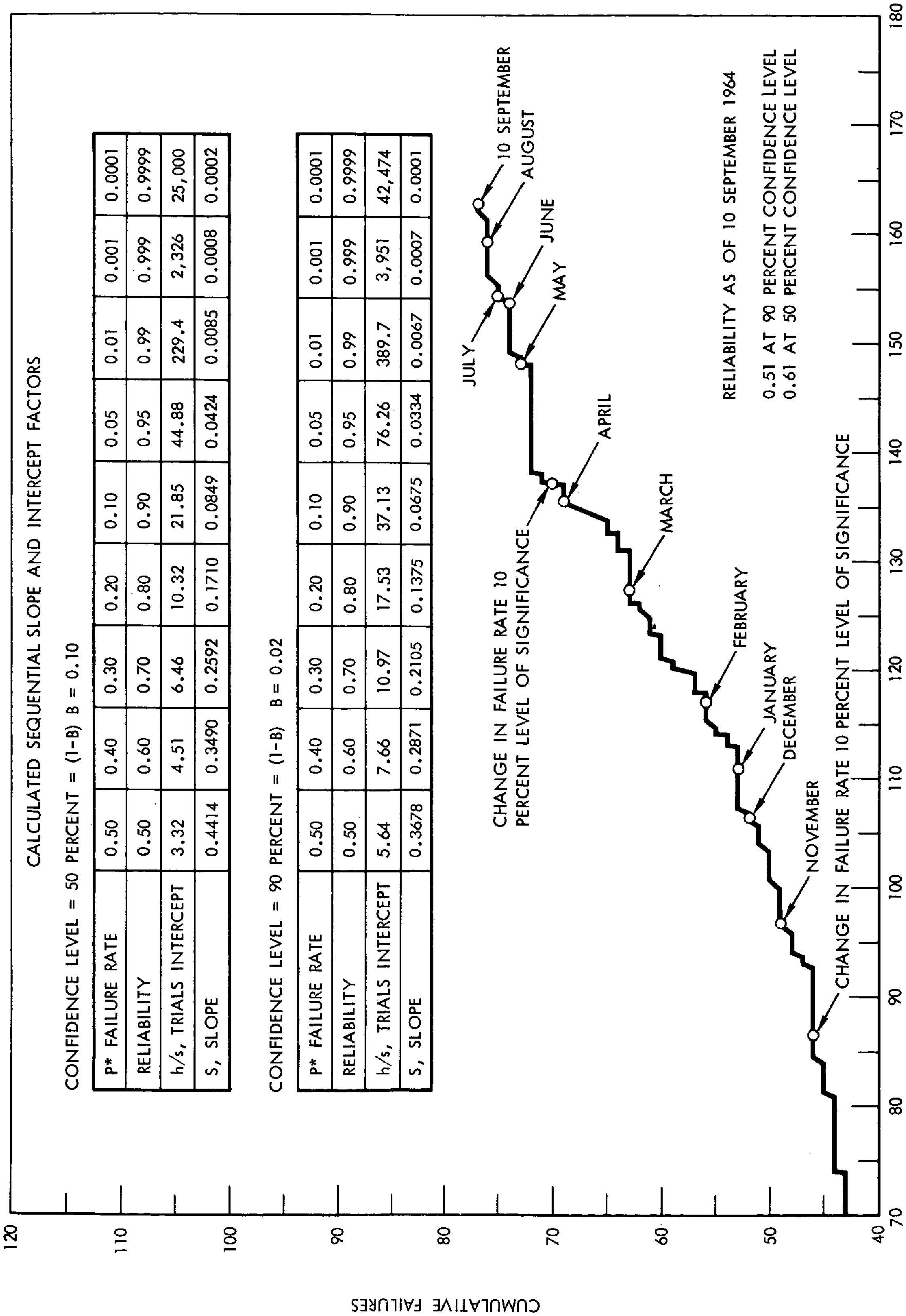

Figure 27. SPS Sequential Growth Plot

[redacted]

in Figure 27, no reliability increase is demonstrated by this method because the effort to develop an injector exhibiting specification performance in stable operation and compatibility with the thrust chamber has not yet been successful. Three more development attempts failed during the last quarter. They are described below:

a. Injector PN 707046-9 (5-4-2) (POUL 41-56)

During mission duty-cycle firing tests 1.2-11-DAJ-010, 011, and 012, the injector popped intermittently during three long-duration firings. Post-firing examination did not indicate any reason (such as intermanifold leakage) for these combustion perturbances, and they have consequently been attributed to marginal stability of the injector pattern. The use of pattern POUL 41-56 has been discontinued because of chamber gouging as well as the popping.

b. Injector PN 707046-1, SN 0000013 (5-4-4) (POUL 41-26)

At the conclusion of 524 seconds of a mission duty-cycle test, 1.2-08-DAJ-007, 008, and 009, a hole 1/16 inch by 3/16 inch was found in the edge of one baffle. The injector was modified to a low baffle, 5-4-2, configuration, but the pattern, which was compatible, was not changed.

c. Injector PN 70746-1, SN 0000010, (5-4-4) (POUL 41-30)

During a 30-second checkout test, 1.2-08-DAJ-006, moderate detonations occurred. Post-test checks revealed no reason for these detonations, and they were consequently attributed to marginal pattern stability. The pattern was modified to POUL 51-36.

3. The subcontractor was directed to furnish reliability assessments of major engine-performance parameters, as soon as sufficient data had been generated by the AEDC Phase II test program, to provide a more accurate vacuum-thrust coefficient. Engine parameters will be assessed in a suitable statistical manner to indicate the probability of meeting the procurement specification requirements.

4. The current assessment of the development and prototype engine component reliabilities is given in Table 20. These data at 50-percent and 90-percent confidence levels have been extracted from the appendix to Aerojet report 3865-01-24, dated 15 July 1964.

[redacted]

Table 20. Current Assessment of Service Module Engine Prototype Components

Component	Confidence Level		Remarks
	50 percent	90 percent	
Electrical harness (operate)	NA	NA	No test data available. Testing in progress.
Propellant line assembly (operate) (flexure)	0. 99976	0. 99916	No operational tests using prototype lines to date. Cycles accumulated on bellows -- PN's 088069 and 088068.
Bipropellant valve assembly	NA	NA	No prototype data available. Testing of prototype valves in progress.
Thrust chamber assembly			
Injector	0. 17942	0. 04979	Tests accumulated on 5-4-4 injectors.
Thrust chamber			Prototype chambers awaiting initial testing.
Nozzle extension	0. 64500	0. 36225	Time accumulated from AEDC testing.
Thrust mount assembly Gimbal ring	NA	NA	No testing subsequent to redesign. Testing will commence prior to next report.
Gimbal bearings (four)	0. 999335	0. 997796	No testing since last report
Gimbal actuator assembly	NA	NA	No test data available. Testing now in progress.
DEVELOPMENT COMPONENTS			
Electrical harness	0. 92063	0. 75980	Time accumulated on PN's 020293 and 020294
Propellant lines	0. 56694	0. 26874	Cycles accumulated from engine start - stops

NA = Not applicable

[redacted]

~~CONFIDENTIAL~~ [redacted]

Table 20. Current Assessment of Service Module Engine Prototype Components (Cont)

Component	Confidence Level		Remarks
	50 percent	90 percent	
DEVELOPMENT COMPONENTS (Cont)			
Bipropellant valve assembly	0.88656	0.83794	Cycles accumulated from engine firings and hydro-testing
Thrust chamber assembly	0.24118	0.11530	Injector time accumulated on injectors with Patterns POUL 31-10, 31-37, and 31-39
Thrust mount assembly	0.99512	0.98393	No testing since last report
Gimbal actuator assembly	NA	NA	Lear-Siegler equipment inadequate. Testing of Cadillac gauge actuators in progress.

NA = Not applicable

5. Separate assessments of start, steady-state, and shutdown reliabilities have been made from Apollo service module engine hot-firings, weighted to reflect full-duration mission firings. Data were obtained from Aerojet report 3865-01-24, dated 15 July 1964, as follows:

Configuration	Confidence Level	
	50 Percent	90 Percent
Start	0.992	0.9902
Steady-state	0.709	0.6684
Shutdown	0.998	0.9903

SUPPLIER CONTROL

The subcontractor has not yet imposed specific component specifications reflecting the intent of MIL R-27542 on all suppliers. In some cases, there are no time/cycle data and failure and failure-analysis reporting. The subcontractor has been directed to implement this as soon as possible and is conducting a complete reliability survey of supplier activity. Upon completion of this survey, the subcontractor will provide a detailed summary of supplier reliability status and a definitive statement of corrective action keyed to each unsatisfactory condition. Corrective action requests have been sent to the suppliers for failure and time/cycle data, and a firm schedule has been established for auditing each supplier's activity.

TEST PROGRAM

Engine Acceptance Tests

There have been no acceptance tests of a complete engine during this report period. The injector has been the pacing item for engine S/N 0000010, previously scheduled for acceptance firing in July and delivery in August. Injector S/N AFF-64 satisfactorily completed the component acceptance test the first week of September, and engine buildup is in process. Delivery of S/N 0000010 was rescheduled for the last week in October.

The two-month slip in scheduled delivery results from (1) the use of a marginal brazing process for fabrication of the unbaffled-type injectors and (2) failure of Aerojet to develop and implement an in-process braze-joint inspection procedure capable of detecting all unsatisfactory and unsound braze areas prior to subjecting the injectors to component acceptance tests.

Prior to incorporation of injector S/N AFF-64 into the engine buildup, four additional brazed injectors had been scheduled for buildup into engine S/N 0000010 and were rejected as follows:

S/N AFF-75 and AFF-78 - Braze cracks developed during compatibility tests.

S/N AFF-52 - Unacceptable repair to orifice obstruction

S/N AFF-72 - Interchannel leakage during leak check

Use of unbaffled and brazed injectors in acceptance tests of complete engines will be limited to S/N 0000010 (second deliverable), S/N 0000017 (third deliverable), and S/N 0000009 and S/N 000011 (AEDC). The latter two engines will be field-retrofitted with dynamically stable, welded injectors. The dynamically stable injector program, now implemented, will completely eliminate the problems relative to brazed joints and inspection thereof.

Qualification Tests

The engine qualification program has been subjected to major realignment consistent with cost-reduction objectives, redefinition of Block I orbital-qualification requirements, and implementation of the dynamically stable injector program. Cognizant S&ID groups determined that even though electromagnetic interference, boost vibration, and explosive-proof testing were eliminated from the environmental tests, mission requirements could still be met. Statistically planned sequential tests and improved utilization of test hardware for the balance of the qualification program will yield adequate test data for reliability and performance evaluation of Block I requirements.

Sea-level environmental qualification tests of two engines (S/N 0000021 and S/N 0000022) are now scheduled at Sacramento for the period of 27 March 1965 through 8 May 1965, with subsequent sea-level firing qualification tests to be concluded the third week of July 1965. Six ablative thrust chambers, in addition to the two chambers incorporated into initial buildup, will be used to support the sea-level qualification tests.

Altitude environmental qualification tests of two additional engines (S/N 0000023 and S/N 000025) are scheduled at AEDC for the period of 20 March 1965 through 1 May 1965, with firings at simulated altitude conditions to be concluded the fourth week of July 1965. Six additional ablative thrust chambers will be utilized to support this program.

Extension of the qualification test schedule, as noted above, will permit a thorough evaluation of candidate orifice patterns and baffle configurations prior to the design freeze for fabrication and component test of dynamically stable injectors to support tests of all qualification engines.

SUBCONTRACTOR MANAGEMENT

The format and content of an acceptable end-item data package has been the subject of several coordination meetings between S&ID and Aerojet Reliability and Quality Control personnel. As a result of these negotiations, Aerojet has submitted a sample data package for S&ID review. The sample package is acceptable to S&ID Reliability except for the omission of three specific documents necessary for (1) reliability evaluation of the complete acceptance test data and (2) surveillance of potential reliability degradation subsequent to initial delivery of the hardware. The documents not included in the sample package are:

1. Test data sheets for unsuccessful as well as successful acceptance tests of the specific component/subassemblies comprising the deliverable end item
2. Engine static firing record
3. Engine historical record

Inclusion of these documents in the data package for the second deliverable engine (S/N 0000010) and all subsequent deliverable engines is being negotiated with Aerojet.

PROPELLANT MANAGEMENT

SUMMARY

During the past quarter suppliers who were previously deliquent in submitting reliability information provided adequate information to S&ID. Review of these data indicates that these suppliers have gained reliability competance.

Reliability evaluation of the positive expulsion tanks has been hampered by the rapid development. Changes have occurred with such frequency that the attempts at statistical analyses have resulted in low confidence conclusions.

The test-point couplings and the relief valve for the service propulsion system have successfully completed the qualification test program. The pressurant and propellant reservoirs are in qualification test. The remainder of the components of the service propulsion propellant feed system are in design verification test. During testing of the check valve, connector, solenoid valve, and regulator, problems were experienced which delayed test completion.

The test programs for components of the SPS propellant feed systems were reviewed relative to possibilities of reducing expenditures for Fiscal Year 1965. Since most components were well into the test program, cost reduction was considered to be feasible only on the propellant utilization gauging system.

ANALYSIS

SPS and RCS Test Point Couplings

An evaluation meeting was held with the coupling supplier during the last report period. The supplier had submitted a reliability report that predicted that the test-point couplings would meet the NAA-required reliability; however, a failure mode and effects analysis was not submitted. Reliability asked for such an analysis, and the supplier is working on it. A preliminary logic diagram was prepared by Reliability to provide the supplier with a model and to fulfill an S&ID immediate need. The diagram was discussed with the supplier, and substantial agreement was reached.

The existing helium solenoid valve incorporates a position indicator, which is essential. The supplier has not specified high reliability in this indicator. To provide sufficient surveillance for assurance of future reliability increase, S&ID has asked that this indicator become a high reliability item, with all the requirements of formal identification and traceability.

RCS Propellant Isolation Valve

As discussed in the previous quarterly report, a failure that occurred in a breadboard test of the subject isolation valves gave rise to emphasis on a failure mode in which the valve-position intelligence did not indicate a functional valve failure. Reexamination of the basic premise that valve position intelligence is required has resulted in a recommendation that the position-intelligence requirement be removed from the SM RCS isolation valves. This is possible because other means of downstream failure detection are available in the propellant gauging. If special Engineering tests show no propellant contamination of the piping downstream from the propellant burst disc as a result of pad abort, the isolation valve in the CM RCS can be removed entirely. No detection means are available in the CM to make use of this isolation valve.

TEST PROGRAM

The test program for the service module propulsion propellant utilization and gauging system was reviewed relative to cost reduction for Fiscal Year 1965, and it was determined that two systems could be deleted from the Block I qualification program. Complete qualification is to be accomplished for the Block II configurations.

The propellant compatibility temperature and exposure duration requirements for the check valve are being evaluated. Latest information indicates a possibility that the propellant exposure test must be performed at a higher temperature than previously required or that temperature control must be provided for the check valve. A research of propellant exposure launch and mission requirements indicated higher temperatures for longer durations than are currently used in the test program. Requirements for propellant exposure testing have previously been outlined.

Requirements for explosion-proof design and testing and suggested test methods were outlined. Implementation of the suggested program, however, may be prohibited by budgetary considerations. Therefore, an analysis is being considered to determine if less expensive methods to resolve the explosion proof problem are possible.

[redacted]

PROBLEM AREAS

Design verification testing of the flexible connector for the SPS propellant feed-engine interface has not begun because of a failure during acceptance-test pressure application. The bellows bowed and assumed a permanent set. This was thought to be a result of the restraining device's not being torqued to the proper value or a material structure effect due to the heat of the brazing operation. Apollo Reliability will monitor redesign as a result of the failure analysis.

The check valve has not completed design verification testing because the unit that had been subjected to N_2O_4 propellant exposure exhibited excessive leakage after vibration testing. The unit, which had not been subjected to propellant exposure testing, successfully passed vibration testing. It is believed that buna-type seal materials are marginal for use in N_2O_4 and that deterioritation of the buna is accelerated as temperature is increased. Negotiations are presently underway with the supplier to provide a redesigned unit with seating material, possibly Teflon, which will be compatible with the N_2O_4 propellant.

The solenoid valve dielectric failure mentioned in the previous report is felt to be solvable by hermetic sealing and potting to cover appropriate connections completely. Change to a forged-valve housing is also planned as a method to eliminate housing distortion observed during pressurization.

During development testing of the PUG propellant control valve, discrepancies were noted between actual valve position and valve readout positions. This was due to excessive tolerances and flexibility between valve parts. The dead bond has been eliminated by closer control of tolerances and beefing up the valve gates.

The SPS pressure regulator had an O-ring failure in the piston seat of the primary controller. In both cases, the failure was excessive leakage after 500 cycles of the endurance test conducted during delta-velocity testing. Exploratory testing is being conducted in an attempt to determine the cause of failure and the most appropriate corrective measure.

Tests of two regulators in a parallel arrangement, such as in the SPS, revealed large pressure-surge variations on the outlet. These variations diminished considerably downstream. This condition was more noticeable in a test wherein the two regulators were set to work at pressures 1-psi different from each other. Complete test information is not now available for a thorough analysis. Testing is continuing in an effort to gain enough information to determine a correction for the problem.

[redacted]

RCS Positive Expulsion Tanks

The positive-expulsion-tank supplier has had difficulty producing an acceptable tank design. Major deficiencies have been low cycle life and poor expulsion efficiency. These problems are believed to have been caused by ply separation or pin holes. The supplier has initiated studies to determine the causes and find a design that eliminates those problems. To date, all tests and studies have been unsuccessful or inconclusive.

The supplier's reliability personnel have participated in design reviews and have conducted statistical evaluation of laboratory and engineering tests. The statistical evaluations have been inconclusive because the sample sizes have been too small, the failure mode and effects analysis has not been updated, and assessments have had low confidence since the design has been in a state of flux, and testing information is only available in small sample sizes.

The supplier has proposed two design changes that will be evaluated shortly. One is use of a single-ply, 6-mil, Teflon bladder in place of the present three plys of 3-mil thickness. This change is being made to eliminate ply separation, which has caused bladder failures and reduced expulsion efficiency. The second is use of a liquid side vent. This changes the filling procedure, allowing the tank to be filled without first pulling a vacuum, thereby minimizing the amount of stresses induced by the fill procedure. The supplier is proposing a development program to evaluate the design changes. In the interim, the supplier will continue the present development program until modified by S&ID.

SPS Relief Valve

Several coordination meetings were held with the relief-valve supplier to discuss the problems mentioned in the Tenth Quarterly Reliability Status Report. The supplier was assisted in preparing his reliability analysis. The analysis has been completed, and preliminary copies show vast improvement. Close surveillance will still be necessary to ensure an adequate reliability program.

SPS Helium Solenoid Valve

Recent tests have indicated several operational problems. These problems were outwardly manifested as main poppet binding, but actually were caused by warpage and deformation of the valve body. The supplier has replaced the existing two-piece, machined, welded body with a forged housing to eliminate welding deformation.

PLANNED ACTIVITIES

Systems compatibility tests are scheduled on the SPS regulator and solenoid valve relative to component interrelationships. Surge-pressure effects resulting from fast actuation of the solenoid valve, and regulator flow and regulation phenomena resulting from the parallel regulator arrangement will be investigated.

IV. GROUND SUPPORT EQUIPMENT

Reliability analyses were performed primarily on mission-essential equipment. The most recent survey lists 91 end items that are considered essential; these are listed in Table 21. (Because of the large number of tables and figures in this section, they are all placed after the text.) Information on mission time and service life is not available at present, but will be included in a future report.

EQUIPMENT ANALYSES

During the report period, failure mode effect analyses (FMEA) were performed on several items of mission-essential GSE. Table 22 lists common terms and definitions for this effort.

PYROTECHNIC INITIATOR SUBSTITUTE UNIT

The failure mode effect analysis (Table 23) shows one first-order undetectable failure mode and five first-order detectable failure modes within this unit (model A14-139).

The undetectable first-order failure mode exists if the 1-ohm load is open. It would not be possible to detect if a resistance in the input line were present that was large enough to attenuate the voltage and prevent it from firing the squib, but low enough to energize the input relay and show a "go" indication. Even though this mode of failure is unlikely, it is recommended that during "go" testing a means of monitoring the instantaneous current be provided to ensure that the test is valid.

The five first-order detectable failure modes are all the same failure mode, but represent five different possibilities of occurrence. The mode is the inability of disconnecting the 1-ohm load from the spacecraft battery after a "go" indication has been obtained. Fuses to protect the battery are located in the spacecraft; however, it is recommended that fuses be used in the substitute unit in series with the input signal so that, if this failure mode does occur, fuse replacement can be limited to the GSE.

ACCEPTANCE CHECKOUT EQUIPMENT

The failure mode effect analyses (Tables 24 to 31) on the ACE response carry-on signal conditioners (models C14-211 to -215) were revised to reflect the latest design changes.

A preliminary actual parts count reliability prediction on the miniaturized data interleaver, with AVCO failure rates at 20-percent stress level, 25 C, and K environmental = 1, resulted in an MTBF of 2880 hours. This is close to the original reliability objective of 3000 hours.

A revised actual parts count for the multiplexer portion of the ACE-SC adapter servicing equipment (Table 32) resulted in an MTBF of 482 hours. The low MTBF is generally due to the inherent complexity of the system and particularly due to the digital multiplexer, which caused approximately 60 percent of the total failures.

SPS CHECKOUT AND FIRING CONTROL

A failure rate prediction for this unit (model C14-602) gave a satisfactory MTBF of 682 hours for Bays 1 and 2, including the thrust vector control and the engine on-off test set. The failure rate prediction for the Bays 3, 4, 5, and 6 gave an MTBF of 295.44 hours, which is far below the required value of 600 hours. The total MTBF for all six bays is 206 hours. The probability that the unit will operate 10 hours without failure is 95 percent.

A stress analysis made on the components of Bays 3, 4, 5, and 6 indicates that the components are stressed below their maximum ratings and that the transistors are operated well within their maximum dissipation curves.

PROPELLANT SERVICING UNITS

A failure mode effect analysis was performed on the diode matrix which implements the operating mode selection for the propellant servicing units (S14-002 and -008-201). The analysis revealed no first-order failure modes that could cause personnel hazard, mission failure, or serious countdown delay. Table 33 indicates 25 detectable second-order, 1 third-order, and 32 fourth-order failure modes. The addition of suppressors across each coil was recommended to preclude damage by circuit transients.

SINGLE-POINT FAILURE SUMMARY

The subsystem single-point reliability block diagrams, Figures 28 to 37, represent in serial format the utilization of ground support equipment in support of Boilerplate 14. As House Spacecraft No. 1, Boilerplate 14 will simulate and support the unmanned supercircular mission alloted to Spacecraft 009 by evaluating the interfaces between its subsystems and related GSE. These figures, however, only represent the applicable GSE in single-point failure format.

PROBLEM ANALYSES

COMMON-USE GSE

A joint reliability plan for LEM common-use GSE, defining S&ID and Grumman Aircraft tasks and responsibilities, has been developed and submitted for NASA and Grumman approval. Twenty-nine LEM common-use items have been selected for delivery to Grumman. Common-use equipment classified as mission essential are indicated in Table 21 by an "L" in the Remarks column. The following additional common-use items are classified as mission support equipment and were therefore not listed in Table 21:

Model	Nomenclature
C14-405	Spacecraft instrumentation test system
S14-002	Helium booster unit
S14-062	Helium ready storage container

Note: Third-order failure mode; MTBF and FMEA data not available.

HAZARDOUS AREAS

A hazardous area checklist with implementing instructions was prepared and presented to the responsible GSE design groups. An examination of methods used to conform with MSFC drawing 10MO1071, Design Requirements for Hazardous Areas, revealed the following deficiencies:

1. Accuracy tolerances on purge pressure sensors are greater than the automatic shutdown pressures.

2. Unit shutdown procedures, should the electrical console purge pressure be lost, are difficult.

These problems will be investigated and resolved with the various design groups and GSE Design Integration.

The checklist technique also revealed discrepancies in the hazardous areas which were used in preparing the B&P proposal for the Qualification

Test Program, MSC-GSE-1B. These errors should not affect the overall B&P cost or explosion-ignition testing effort, but will merely reorient the explosion-ignition test from one model to another.

HYPERGOLIC VAPOR DISPOSAL

According to the failure modes described in design reviews 34 and 55 (Table 21), hazardous hypergolic liquid propellant will be introduced into the toxic vapor disposal units (S14-060 and -061). The responsible groups are attempting to eliminate all first- and second-order failure modes in these and associated units.

IDENTIFICATION AND TRACEABILITY

Identification and traceability ground rules for GSE were reviewed with NASA. Approval of these rules is pending.

SUBCONTRACTOR MANAGEMENT

Cosmodyne

The I&T program and exempt parts list for the LH_2 and LO_2 transfer units were clarified at a meeting at the Cosmodyne Corporation. In addition, the FMEA and reliability predictions for the fuel and oxidizer ready storage units were discussed. Cosmodyne's I&T program and exempt parts list will be revised to include the requirements imposed upon their subtier suppliers.

Cosmodyne's FMEA for the ready storage units was not acceptable since it did not include the complete system functional analyses. The FMEA for the fuel and oxidizer mobile storage units indicated several catastrophic failures. However, because of contract limitations, Cosmodyne will not be required to perform further analyses of these units. Instead, Apollo Reliability will expend additional time analyzing the other modes of operation for personnel hazard.

Remanco

Considerable effort was expended during the report period evaluating and recommending changes to the power supplies and precision meters used in the SPS checkout and firing control unit. The power supply problems were traced to excessive temperatures within the unit; these have been reduced and the problem has been resolved. The meter was modified and improved by adding a null adjustment at the rear of the meter, and a resonance problem was eliminated by increasing the tension of the taut band. The dial face is now secured with screws, which maintain its fixed position and eliminate pointer drag.

Control Data

A review of Control Data's FMEA revealed that the present design does not comply with specifications for the relay module requirements of a one-and-only-one subgroup select check. This and other first-order failure modes were documented and submitted to Engineering for design evaluation.

GSE PROGRAMS

QUALIFICATION PROGRAM

A proposed GSE environmental program plan was established in June 1964. The proposed program included 103 test units of GSE, both mission-essential and mission-support equipment. Forty-four mission-essential units were proposed for environmental testing, as follows:

Type of Test	No. of Models to be Tested
Humidity	23
Operating temperature	14
Salt and fog	5
Sand and dust	9
Vibration	18
Acoustics	8
Shock	16
Explosion ignition	21
Simulated duty cycle	40

This testing, as well as qualification by similarity of units and field usage, would qualify 63 mission-essential models prior to the first manned flight. Explosion-ignition testing was proposed on 59 additional support models. EMI testing, which was covered by CCA 80, was proposed on a total of 66 test items.

In an attempt to reduce the costs of the program, an Apollo GSE electromagnetic compatibility (EMC) test requirements conference was held in August 1964. According to the ground rules established at the conference, EMC tests will be performed on very critical electronic items only. Fourteen models were placed in Class I and six in Class 2.

A summary qualification test matrix was prepared and presented to NASA in September 1964 which required only 15 test units, thus reducing the cost of the program substantially. A new proposal, calling for 36 test units and including test method justification, was presented to NASA in October 1964. This proposal described the method by which hermetically sealed components and end-items located in hazardous areas will be verified and justified the qualification of the large servicing GSE by performing normal operational testing at KSC.

TEST PROGRAM

The safety aspects of testing the relief valves after installation were evaluated at a design review. Proof-pressure testing on the servicing GSE end-item, as well as on the component level, was recommended. Component-level testing does not check out the piping installation or ensure that its connections are properly installed or will withstand proof pressure. The present test specification on pressure systems has not been approved pending resolution of test requirements. Because of these problems, an extensive redesign of this unit is anticipated.

OPERATIONAL READINESS PROGRAM

The prime objective of the operational readiness program is to assure that the Apollo spacecraft and mission-essential equipment will meet the launch window. The program requirements are based on and derived from reliability, maintainability, and operational considerations. Probabilistic analyses will be performed only to attain design goals in terms of inherent reliability and maintenance capability or to provide data support for possible design changes. The following departments will assist in evaluating the inherent operational readiness of the equipment:

Reliability
Logistics Engineering
GSE Integration
Crew Systems

The activities of these departments will be coordinated with such other organizations as Apollo Test Operations, Spacecraft and GSE Design, and Systems Engineering.

Failure mode effect analyses will be used to identify all detectable failure modes which could cause launch delays. The possibility of these failure modes occuring will be evaluated in conjunction with equipment use timelines; maintenance task time will subsequently be analyzed to determine the effect of the failure on meeting the launch window. Probabilistic analyses will be performed to the extent necessary to determine the attainment of MTBF design goals. Failure-rate data used in these analysis will be based on the latest available information, including qualification test data and field usage data accrued on specific parts. Failure effects and failure rates, to equipment and subsystem levels, will assist in the derivation and use of any analytical models employed to evaluate launch success.

The following activities were performed during the last quarter:

1. Reliability logic block diagrams of Boilerplate 14/Spacecraft 009, GSE subsystems

2. Single-point failure effect analysis of Boilerplate 14/Spacecraft 009, GSE subsystems

3. Functional utilization diagrams at submodule level of Boilerplate 14/Spacecraft 009, GSE subystems

4. Preliminary Reliability and Logistics Engineering study schedule and task definitions on Apollo GSE operational readiness

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Table 21. Mission-Essential Ground Support Equipment

Unit	Category	Make-Buy	Nomenclature	MTBF (hr)		Remarks
A14-019	ME I	M	Umbilical, spacecraft fluid, and electrical disconnect set	2,400	*	
A14-024	ME I	M	Umbilical fluid electronics disconnect set			Cursory analysis will be performed.
A14-033	ME II	B	ECS suit loop stimuli generator test set	809	L	FMEA being reviewed
A14-034	ME II	B	ECS pressure distribution test set	500		FMEA being prepared at subcontractor's facility
A14-052	ME II	M	Heater power supply, fuel cell, and cryogenic storage system	745	*	
A14-139	ME I	M	Pyrotechnic initiator substitute unit	2,042	*	
A14-003	ME I	M	Pyrotechnic initiator substitute set	2,400	*	
A14-148	ME II	M	Umbilical disconnect purge	600		FMEA in progress at Tulsa facility
A14-172	ME I	M	S-IVB (LEM) adapter umbilical disconnect set			
C14-002	ME II	B	Baroswitch test unit	301		
C14-009	ME II	M	Crew systems checkout group	4,570	*	
C14-019	ME I	M	Test conductor group			
C14-051	ME I	M	Pyrotechnic bench maintenance equipment	5,977	*	
C14-075	ME I	M	Propulsion system fluid checkout unit	844		
C14-112	ME I	M	C-band Radar transponder checkout unit			No FMEA will be made.
C14-177	ME II	B	Launch complex 37B electrical cable set			Cursory analysis will be performed.
C14-180	ME II	B	Launch complex 34 electrical cable set			Cursory analysis will be performed.
C14-187	ME II	M	Electrical cable set			Cursory analysis will be performed.
C14-188	ME II	B	Electrical cable set			Cursory analysis will be performed.

* Denotes FMEA completed

L Denotes LEM common use/GSE

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Table 21. Mission-Essential Ground Support Equipment (Cont)

Unit	Category	Make-Buy	Nomenclature	MTBF (hr)	Remarks
C14-189	ME II	B	Electrical cable set		Cursory analysis will be performed.
C14-192	ME II	M	Umbilical junction box	2,179	*
C14-200	ME I	B	Carry-On receiver and baseplate unit	368	* L
C14-201	ME I	B	Carry-On baseplate unit	368	* L
C14-202	ME I	M	ACE-SC carry-on junction box	10,000	*
C14-210	ME II	B	Carry-On PCM system	2,500	* L
C14-211	ME II	M	Digital signal conditioning and multiplexing unit	324	* L
C14-212	ME II	M	Analog signal conditioning and sampling unit	209	* L
C14-213	ME II	M	G&N signal conditioning and switching matrix unit	895	* L
C14-214	ME II	M	High-sampling-rate signal conditioning unit	1,322	* L
C14-215	ME II	M	Special signal conditioning unit	746	* L
C14-220	ME I	M	Carry-On command stimuli system	5,100	Estimated completion 6 November 1964
C14-230	ME II	M	Data interleaving system	997	*
C14-231	ME I	B	External digital test command system	1,150	* L
C14-232	ME II	M	Miniaturized data interleaving system	434	* L
C14-240	ME II	M	ACE-SC adapter servicing equipment	482	* L
C14-241	ME I	M	Digital test command system service equipment	136	* L
C14-262	ME I	M	ACE dc power supply	600	*
C14-300	ME I	M	GSE/FDS electrical control switching unit		Estimated completion 6 November 1964
C14-410	ME II	B	Space radiation and optical properties measurement set		Estimated completion 20 November 1964

* Denotes FMEA completed

L Denotes LEM common use/GSE

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Table 21. Mission-Essential Ground Support Equipment (Cont)

Unit	Category	Make-Buy	Nomenclature	MTBF (hr)	Remarks
C14-414	ME I	M	Launch control group		*
C14-446	ME I	M	CM RCS fuel fluid distribution system control unit	1,824	*
C14-447	ME I	M	SM RCS fuel fluid distribution system control unit	1,824	*
C14-448	ME I	M	RCS oxidizer fluid distribution system control unit	1,824	*
C14-449	ME I	M	Helium fluid distribution system control unit	1,824	*
C14-451	ME II	B	ELS sequence controller pressure stimuli generator	618	Submitted subcontractor FMEA not acceptable; subcontractor to reevaluate FMEA
C14-455	ME I	M	SPS remote control rack	1,500	*
C14-472	ME II	M	Launch complex 34 electrical cable set		
C14-476	ME I	M	LH_2 fluid distribution system control unit	1,824	*
C14-477	ME I	M	LOX fluid distribution system control unit	1,824	*
C14-480	ME I	M	Initiator stimuli unit	1,410	Estimated completion 20 November 1964
C14-483	ME I	M	RCS valve driver and monitor unit	1,234	*
C14-484	ME II	M	SM external stimuli conditioning unit	600	*
C14-488	ME I	M	SPS oxidizer fluid distribution system control unit	1,824	*
C14-489	ME I	M	SPS fuel fluid distribution system control unit	1,824	*
C14-548	ME II	M	Launch complex 34 servicing tower, fuel side, CM electrical terminal distribution		Estimated completion 6 November 1964
C14-549	ME II	M	Launch complex 34 servicing tower, fuel side, SM electrical terminal distribution		Estimated completion 6 November 1964

* Denotes FMEA completed

L Denotes LEM common use/GSE

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Table 21. Mission-Essential Ground Support Equipment (Cont)

Unit	Category	Make-Buy	Nomenclature	MTBF (hr)	Remarks
C14-550	ME II	M	Launch complex 34, servicing tower, oxidizer side, CM electrical terminal distribution		Estimated completion 6 November 1964
C14-551	ME II	M	Launch complex 34 servicing tower, oxidizer side, SM electrical terminal distribution		Estimated completion 6 November 1964
C14-572	ME I	M	Launch complex 34 umbilical junction box		Cursory analysis will be performed.
C14-574	ME I	M	ACE carry-on cable set		Cursory analysis will be performed.
C14-575	ME I	B	CO_2 sensor calibration unit		
C14-577	ME I	M	ETD oxidizer control area		Cursory analysis will be performed.
C14-578	ME I	M	ETD fuel control area		Cursory analysis will be performed.
C14-579	ME I	M	ETD environmental platform base		Cursory analysis will be performed.
C14-602	ME II	M	SPS checkout and firing control special test unit	206	
C14-605	ME II	M	CM RCS checkout fire control console special test unit	675	*
C14-606	ME II	M	SM RCS checkout fire control console special test unit	840	*
S14-002	ME I	M	N_2/O_2 transfer and conditioning unit	2,100	* L
S14-005	ME I	M	Water transfer unit	1,900	* L
S14-008	ME I	M	Fuel transfer and conditioning unit	2,100	* L
S14-009	ME I	B	Helium transfer unit	3,932	* L
S14-019	ME I	B	Water-glycol service set	410	L FMEA being prepared at subcontractor's facility

* Denotes FMEA completed

L Denotes LEM common use/GSE

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Table 21. Mission-Essential Ground Support Equipment (Cont)

Unit	Category	Make-Buy	Nomenclature	MTBF (hr)	Remarks
S14-026	ME I	B	LH_2 transfer unit	628	* L
S14-032	ME I	B	LO_2 transfer unit	608	* L
S14-041	ME I	M	Fluid distribution system	885	FMEA in progress at Tulsa facility
S14-052	ME II	M	Water-glycol cooling unit	646	*
S14-053	ME I	B	ECS water-glycol, trim control set	780	FMEA being prepared at subcontractor's facility
S14-054	ME II	M	Fuel cell power plant water-glycol servicing set	1,300	*
S14-057	ME I	B	RCS oxidizer servicing unit	2,152	* L
S14-058	ME I	B	Fuel ready storage unit	3,300	L FMEA completed by supplier recommended changes have been submitted to data requirements group
S14-059	ME I	B	Oxidizer ready storage unit	3,300	L
S14-060	ME I	M	Fuel toxic vapor disposal unit		Preliminary FMEA completed by supplier; updated FMEA in progress
S14-061	ME I	M	Oxidizer toxic vapor disposal unit		
S14-063	ME I	M	SM RCS fuel servicing unit	2,152	* L
S14-064	ME I	M	CM RCS fuel servicing unit	2,152	*
S14-065	ME I	B	LO_2 mobile storage unit	872	L Preliminary FMEA received from supplier and comments submitted; updated analyses in progress
S14-066	ME I	B	LH_2 mobile storage unit	836	L
S14-079	ME II	M	Potable water module leak-test unit	8,011	
S14-098	ME I	M	Hydrogen leak detector		Design in progress preliminary prediction analysis indicates MTBF in excess of 80,000 hours.
S14-107	ME I	M	Launch complex 37 fluid distribution system		Insufficient design information for reliability analyses
S14-108	ME I	M	Launch complex 39 fluid distribution system		
S14-119	ME I	M	Lightweight potable water transfer set		

* Denotes FMEA completed

L Denotes LEM common use/GSE

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Table 21. Mission-Essential Ground Support Equipment (Cont)

Category	Definition
ME I: Mission Essential, Criticality I	If an item in this category failed, and the failure went undetected, it could jeopardize crew safety or create a personnel hazard.
ME II: Mission Essential, Criticality II	If an item in this category failed, it could result in extended launch delays for repairs; if the failure went undetected, it could result in mission abort.
MS: Mission Support, Criticality III	If an item in this category failed, it would not result in unsafe conditions, long-lead repairs, or launch delays.

* Denotes FMEA completed

L Denotes LEM common use/GSE

Table 22. Common FMEA Terms and Definitions

Criticality Categories	Failure Mode Order	Corrective Action Classification
Catastrophic	First-Order Failure Mode. Failure of a GSE component which results in personnel hazard or a spacecraft failure, detected or undetected. Loss of equipment by damage.	Unit will be out of service, and will be removed from work area while failed component is being replaced.
Major	Second-Order Failure Mode. Failure of a GSE component which results in extended delay of servicing or checkout function.	Unit will be out of service while replacement or repairs are being made. It may be necessary to remove unit from work area.
Minor	Third-Order Failure Mode. Failure of a GSE component which results in temporary delay of servicing or checkout function.	Minor adjustments or repairs will be made while the servicing or checkout function continues. It will not be necessary to remove unit from work area.
All others	Fourth-Order Failure Mode. Failure of a GSE component which results in no delay in servicing or checkout function.	No corrective action required until servicing or checkout function is completed.

Table 23. FMEA Summary: Pyrotechnic Initiator Substitute Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	1				1					
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	5					5				
Undetectable failure of a GSE component which results in its replacement or repair.			2			2				
Detectable failure of a GSE component which results in its replacement or repair.			26			26				
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS	6		28		1	33				
SUM TOTALS	34				34					

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Table 24. FMEA Summary: ACE-SC Carry-On Junction Box

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		13				13			13	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				13				13	13	
TOTALS		13		13		13		13	26	
SUM TOTALS	26				26				26	

Table 25. FMEA Summary: Digital Signal Conditioning and Sampling Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		868	640			1188	320		1508	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS		868	640			1188	320		1508	
SUM TOTALS	1508				1508				1508	

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Table 26. FMEA Summary: Analog Signal Conditioning and Sampling Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		311				311			311	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS		311				311			311	
SUM TOTALS	311				311				311	

Table 27. FMEA Summary: G&N Signal Conditioning and Sampling Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		42				42			42	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS		42				42			42	
SUM TOTALS	42				42				42	

[redacted]

[redacted]

Table 28. FMEA Summary: High-Sampling-Rate Signal Conditioning Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		52				52			52	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS		52				52			52	
SUM TOTALS	52				52				52	

Table 29. FMEA Summary: Special Signal Conditioning Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		55				55			55	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				1				1	1	
TOTALS		55		1		55		1	56	
SUM TOTALS	56				56				56	

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Table 30. FMEA Summary: External Signal Conditioning Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		190				190			190	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				1				1	1	
TOTALS		190		1		190		1	191	
SUM TOTALS	191				191				191	

Table 31. FMEA Summary: ACE-SC DC Power Supply

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	1								1	
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.						1				
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		10				7	3		10	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				6			4	2	6	
TOTALS	1	10		6		8	7	2	17	
SUM TOTALS	17				17				17	

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Table 32. FMEA Summary: ACE-SC Adapter Servicing Equipment

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.		17	193			17			210	
Detectable failure of a GSE component which results in its replacement or repair.		11				11	193		11	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				1				1	1	
TOTALS		28	193	1		28	193	1	222	
SUM TOTALS	222				222				222	

Table 33. FMEA Summary: Oxidizer and Fuel Transfer and Conditioning Units

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		25				25			7	20
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.			1	32			1	32		
TOTALS		25	1	32		25	1	32	7	20
SUM TOTALS	58				58				27	

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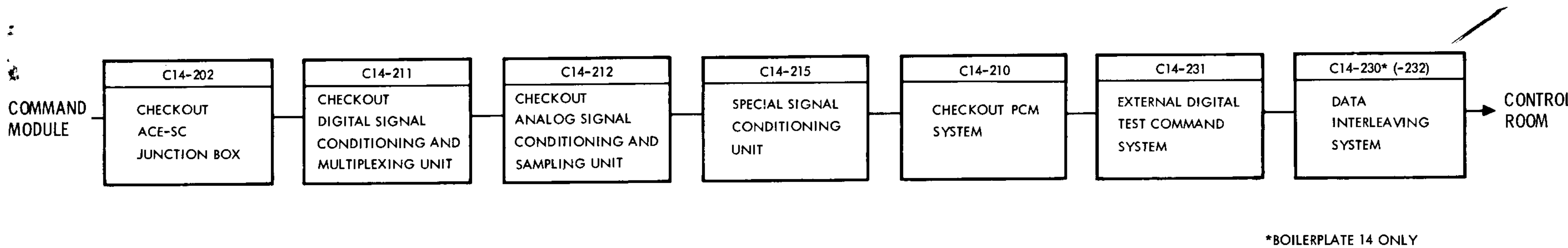

Figure 28. Communication and Instrumentation ACE-SC GSE Utilization

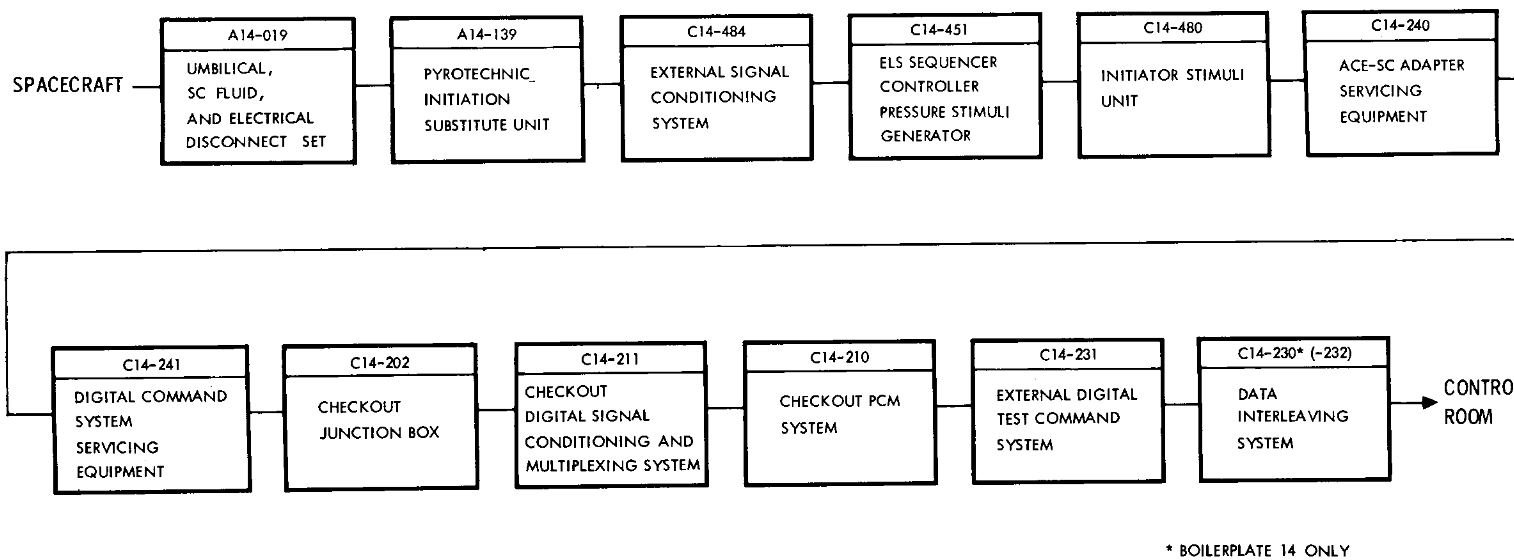

Figure 29. Earth Landing ACE-SC GSE Utilization

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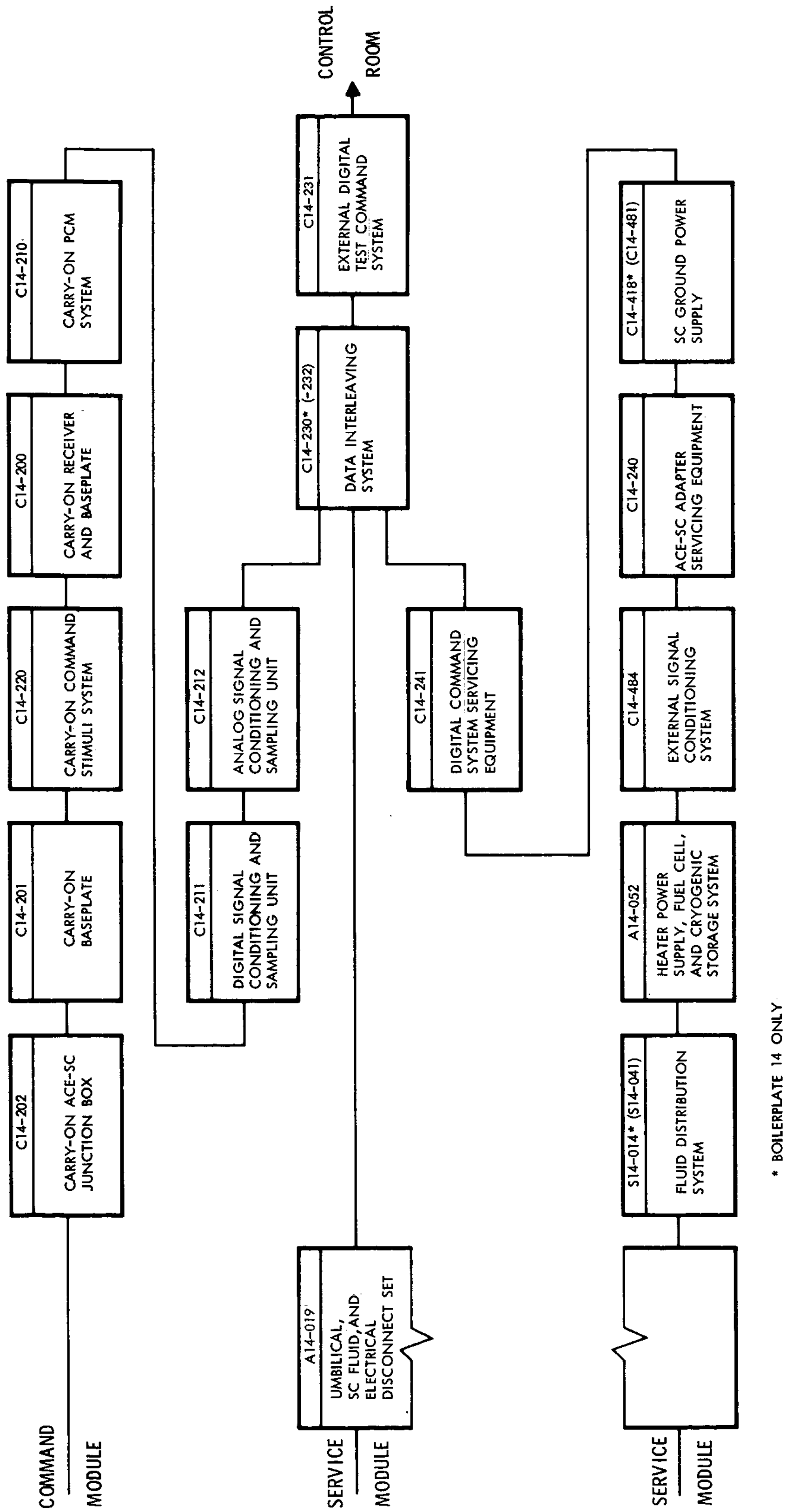

Figure 30. Electrical Power ACE-SC GSE Utilization

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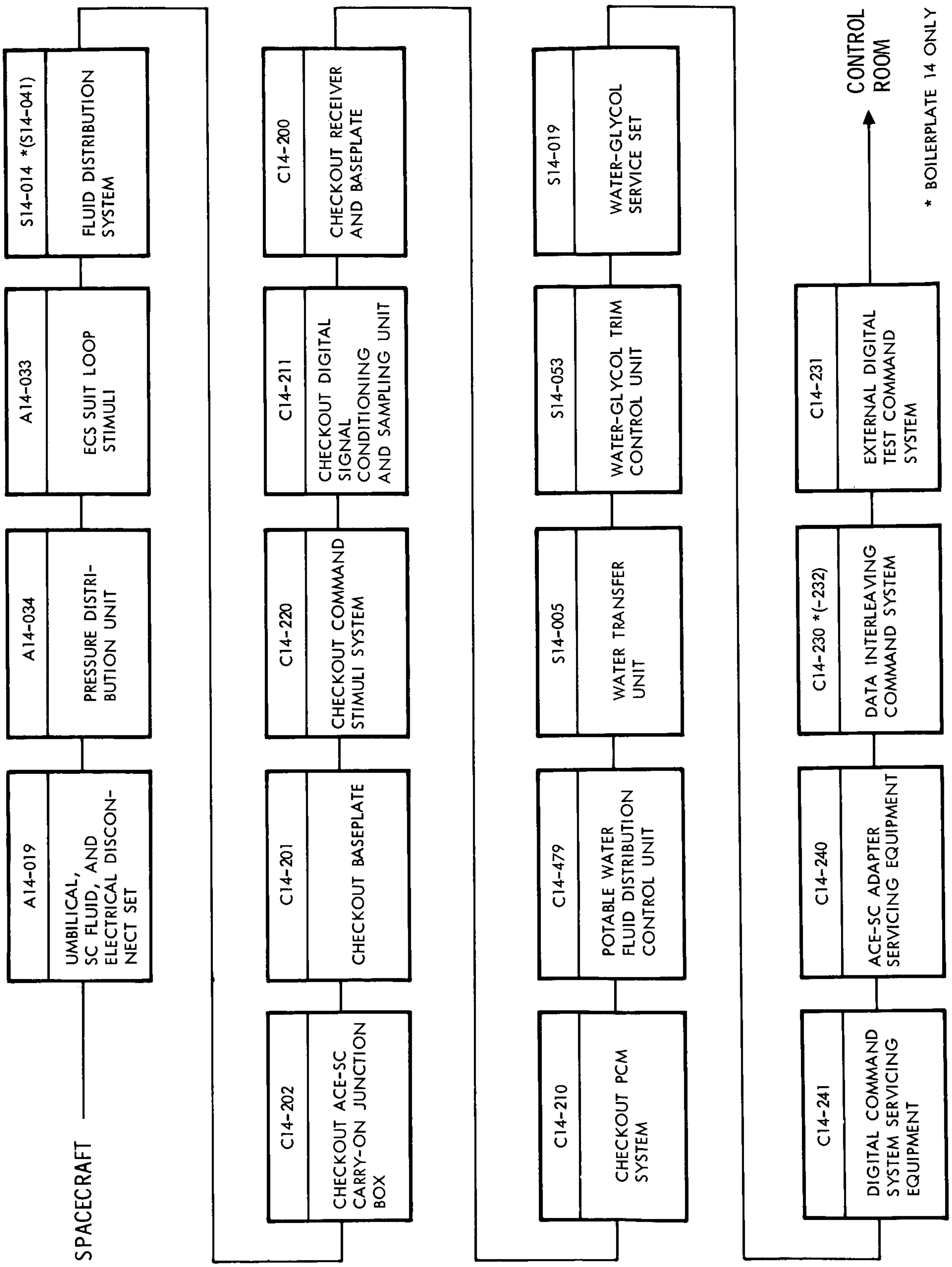

Figure 31. Environmental Control ACE-SC GSE Utilization

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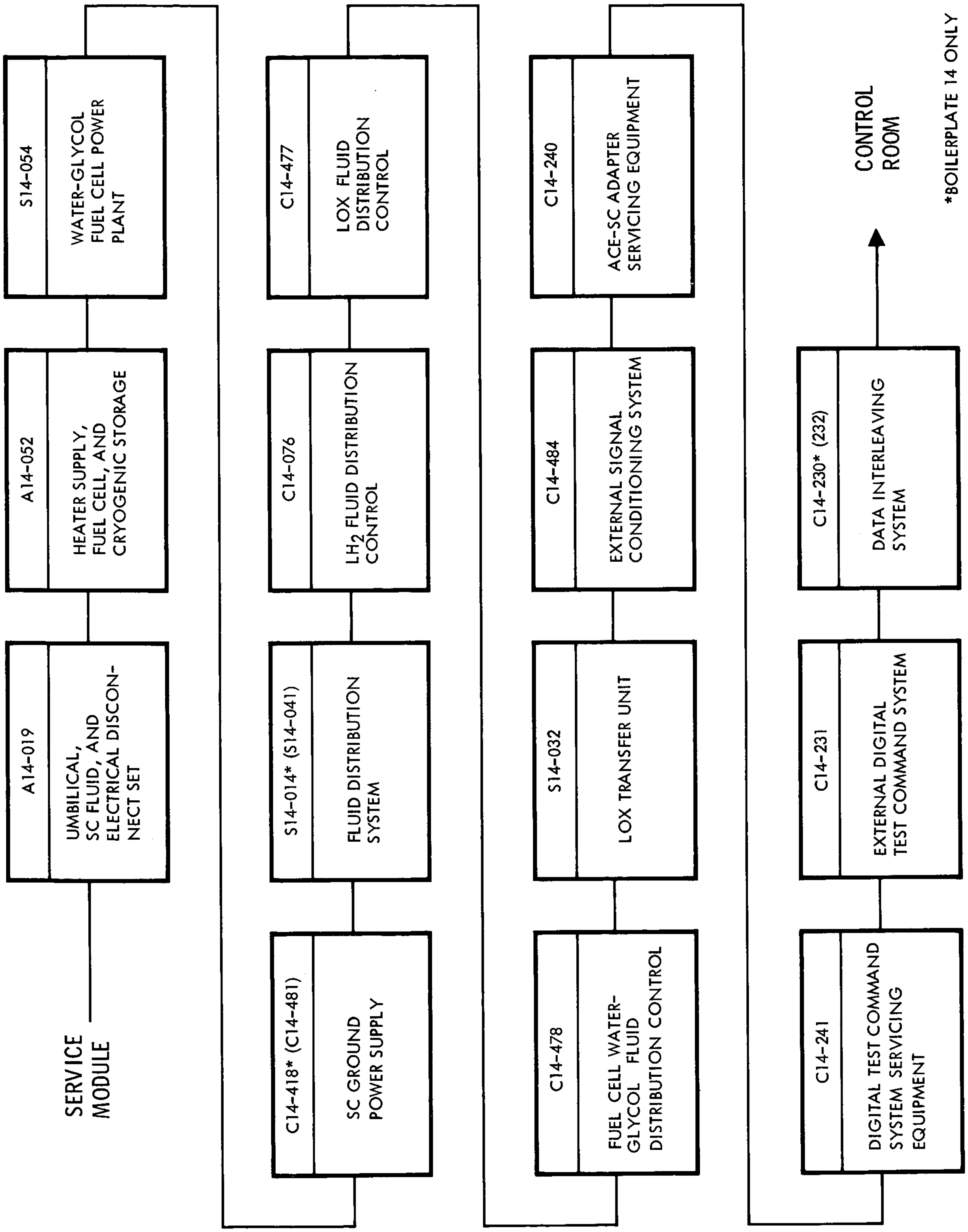

Figure 32. Fuel Cell ACE-SC GSE Utilization

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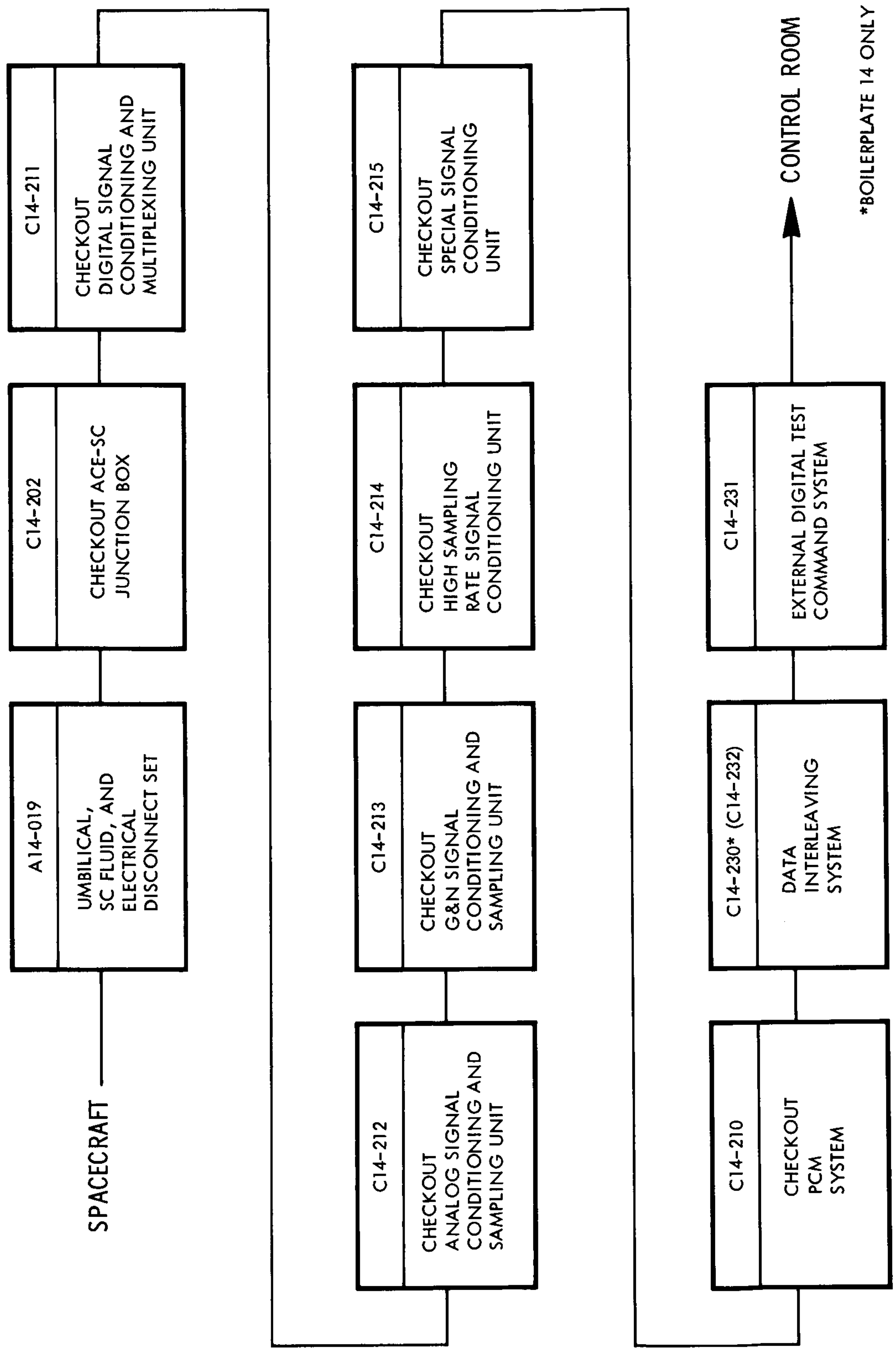

Figure 33. Guidance and Navigation ACE-SC GSE Utilization

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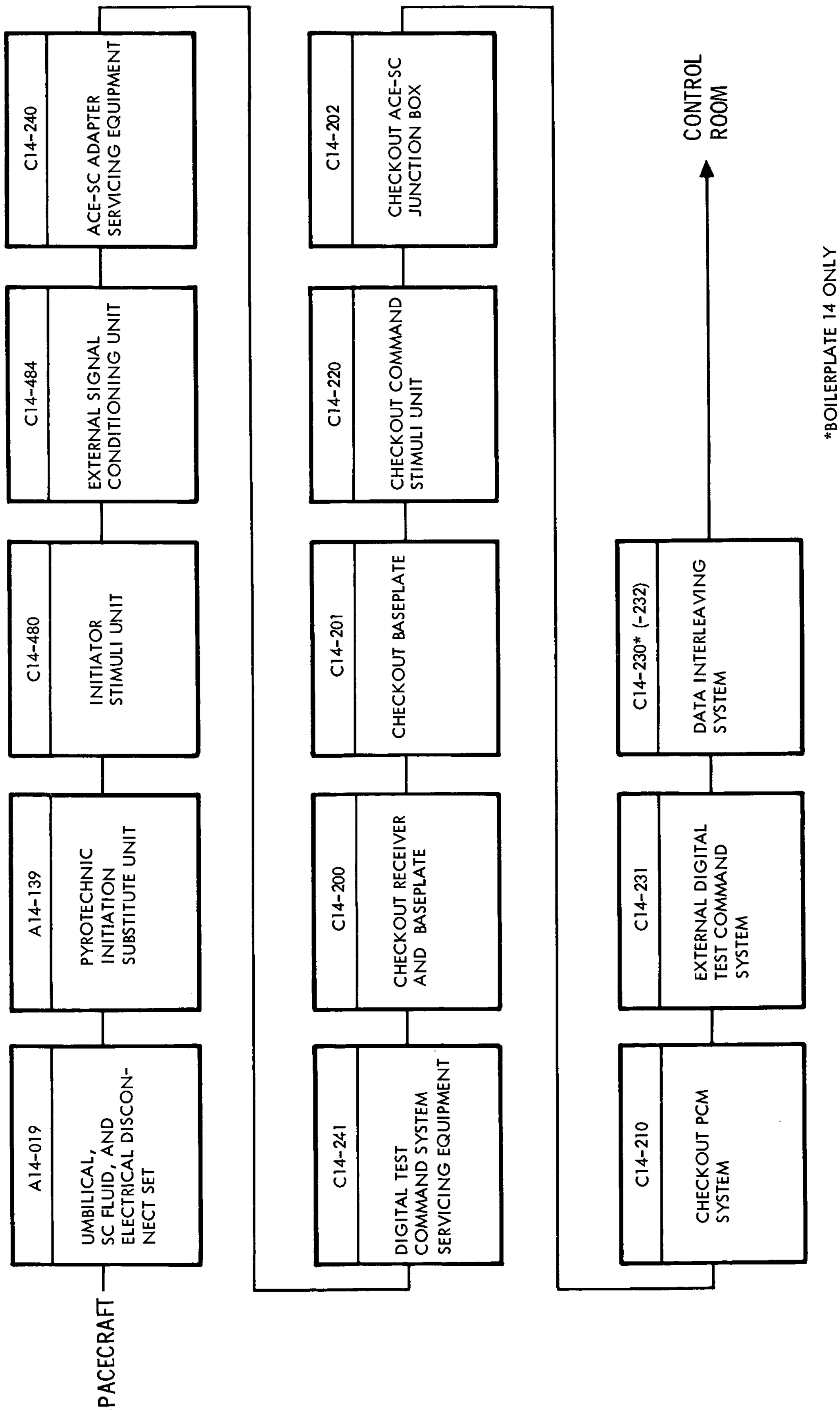

Figure 34. Launch Escape ACE-SC GSE Utilization

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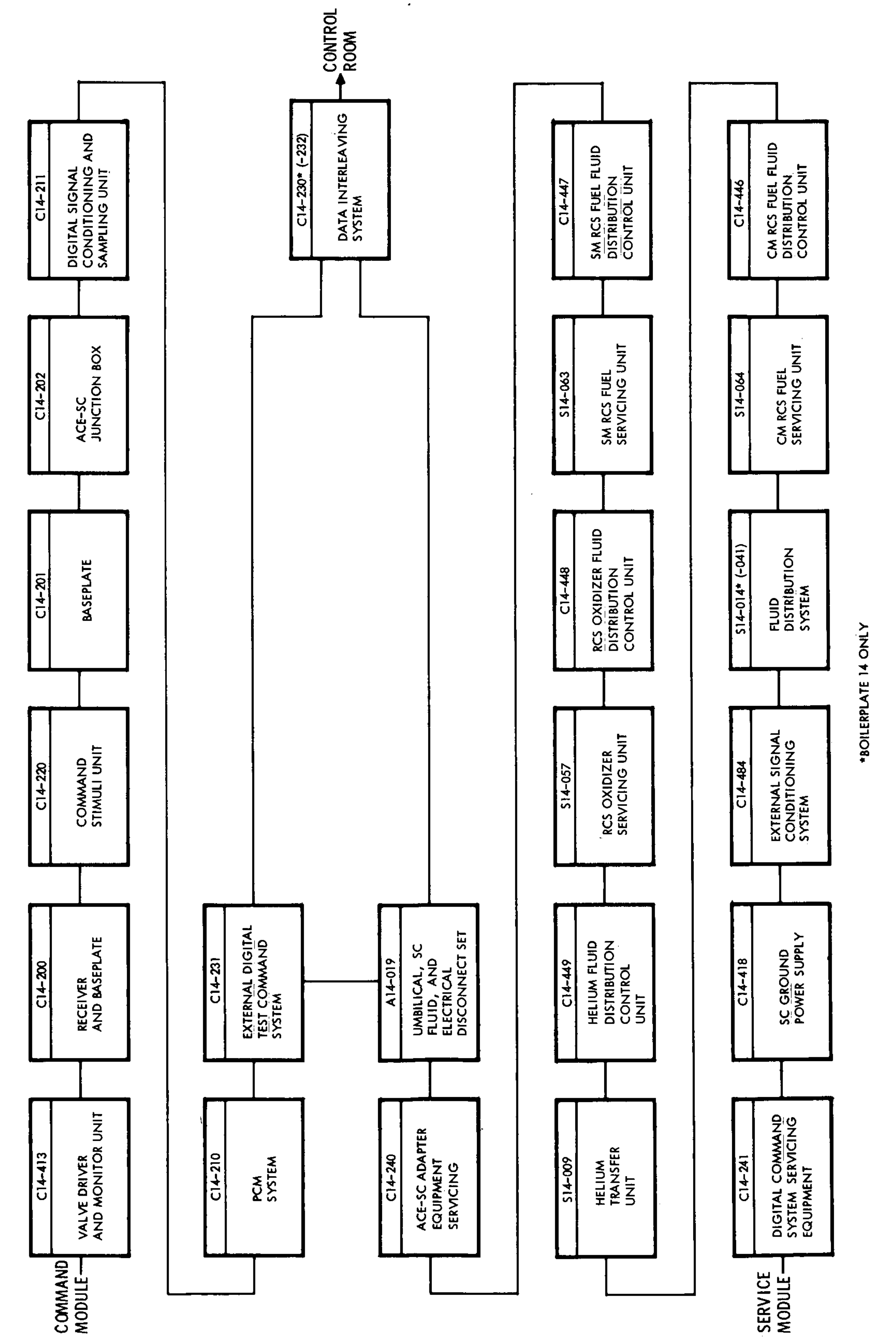

Figure 35. Reaction Control ACE - SC GSE Utilization

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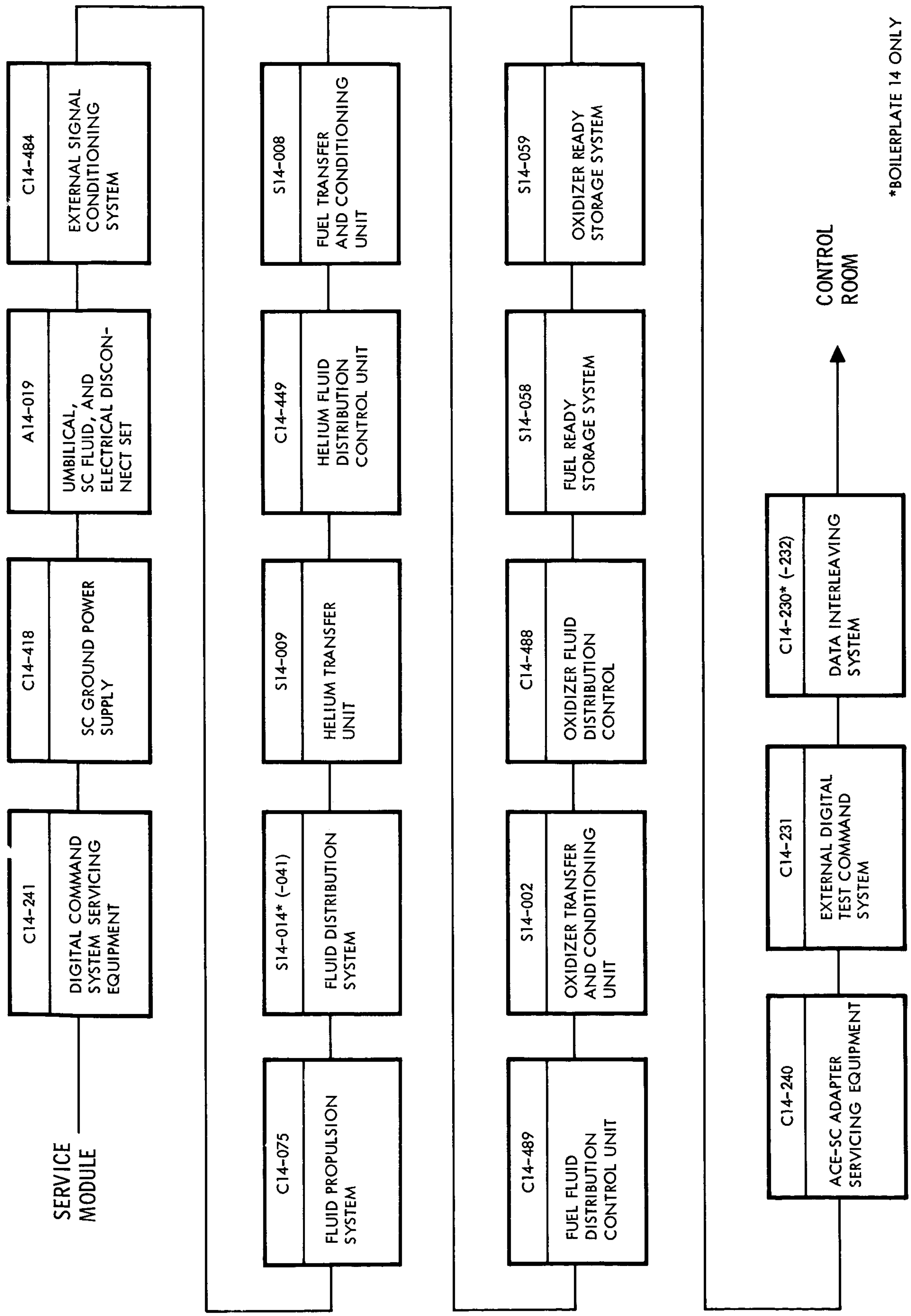

Figure 36. Service Propulsion ACE-SC GSE Utilization

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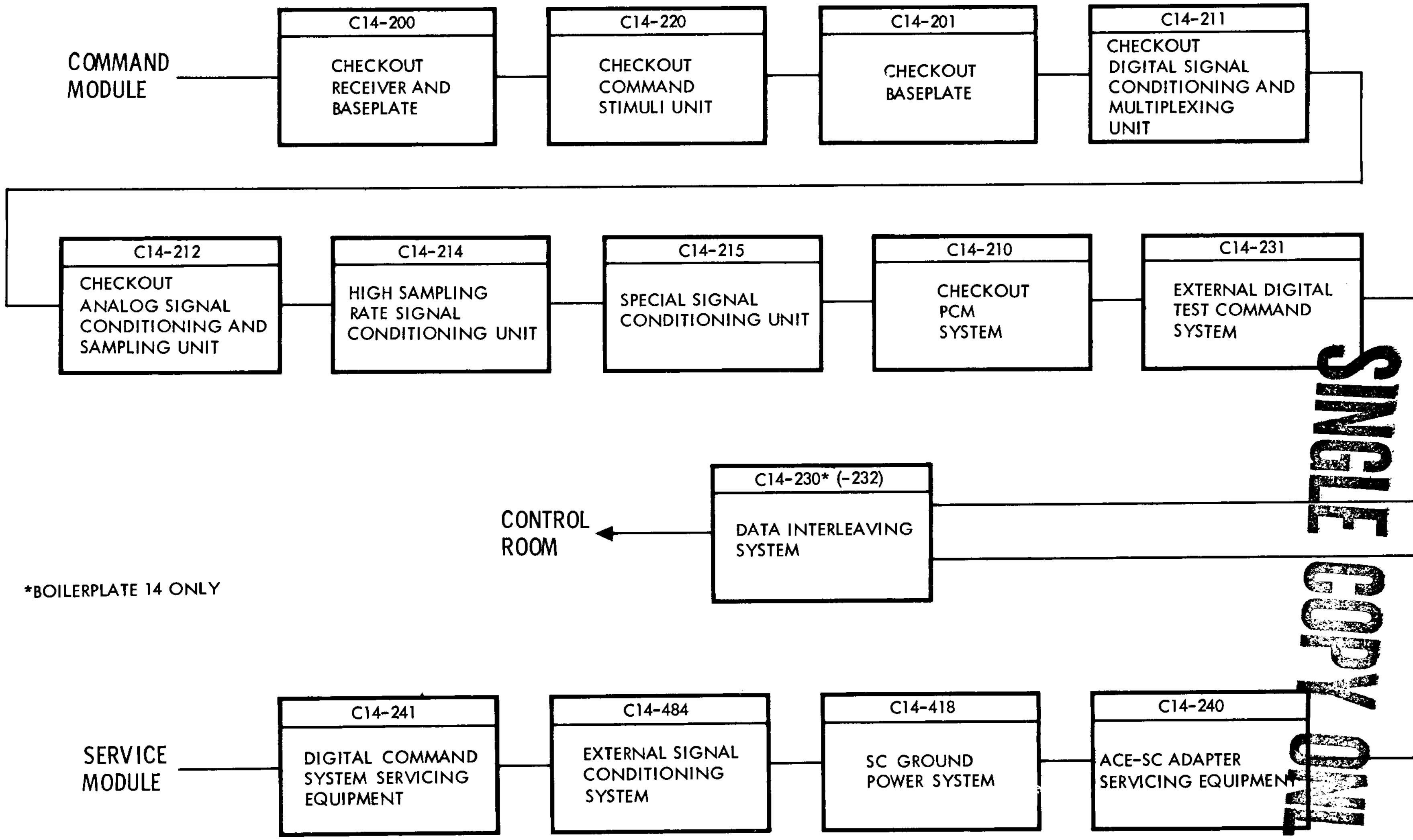

Figure 37. Stabilization and Control ACE-SC GSE Utilization

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